TF 2330

TF 2330

Wave Analyser

INSTRUCTION MANUAL

mi
MARCONI INSTRUMENTS

INSTRUCTION MANUAL

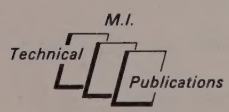
No. EB 2330

for

Wave Analyser

TF 2330

including TF 2330R



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MARCONI INSTRUMENTS LIMITED

ST. ALBANS HERTFORDSHIRE ENGLAND

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Chapter I

General information

1.1 FEATURES

The TF 2330 Wave Analyser provides comprehensive measurement facilities for the analysis of the performance of devices operating within the audio and ultrasonic frequency spectrum. The amplitude of each individual frequency component of a complex signal may be determined in terms of absolute voltage or relative to a fundamental datum level in decibels or in percent.

Basically the instrument comprises a sensitive narrow band tuned voltmeter covering the range 3 μV to 300 V. With a bandwidth of 7 c/s it may be tuned to any frequency from 20 c/s to 50 kc/s; after initial tuning internal automatic frequency control may then be employed to lock it to the signal component to obviate continual retuning, thus ensuring accurate meter readings.

While a signal is being investigated a variable output voltage is available, having the same frequency as the signal component to which the analyser is tuned. When the component is not harmonically connected to any other known component of the input signal, this output may be applied to an external counter for a more accurate determination of its frequency.

Another function of the instrument is to provide a convenient facility for determining frequency responses. A beat frequency oscillator, controlled by the voltmeter tuning and in step with it, provides a variable output voltage which, when set, remains constant over the whole frequency range. By applying this signal to the input of a circuit and monitoring the output with the tuned voltmeter section the response of the circuit can be rapidly ascertained.

TF 2330R is a rack mounting model which differs only in having a special case with flanges for fitting to a 19 inch rack.

An optional accessory is Tunable Rejection Filter TF 2334. This instrument has been designed primarily to extend the measuring range of wave analysers for the measurement of very low level harmonic and intermodulation components (but can also be used in conjunction with a valve voltmeter for approximate distortion factor and frequency measurements).

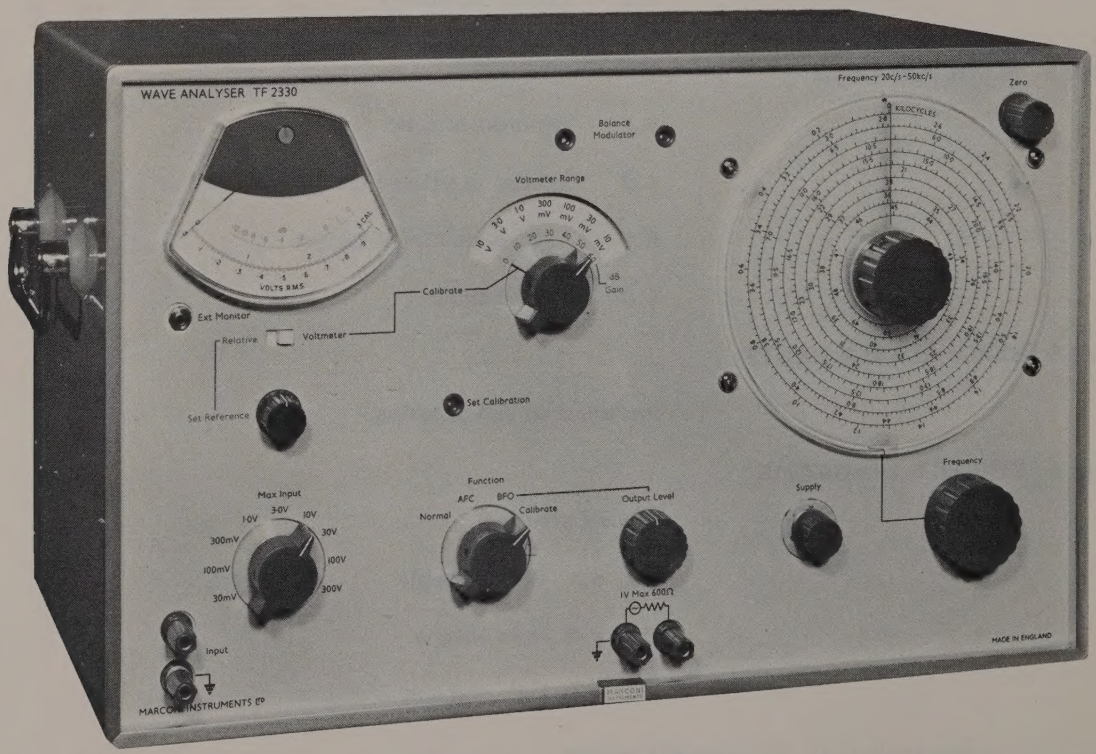


Fig. 1.1 Wave Analyser TF 2330

1.2 DATA SUMMARY

INPUT FREQUENCY

Working range:	20 c/s to 50 kc/s.
Accuracy:	±1%, ±5 c/s.
A. F. C.:	Tuning remains locked to input frequency over ±100 c/s drift.

AMPLITUDE RANGES

Waveform analysis

Range:	Measurements down to -75 dB with respect to any fundamental level between 30 mV and 300 V. For fundamental levels below 30 mV, the measurement range is progressively reduced.

Selective voltage measurement

Range:	3 μV to 300 V in 15 ranges of 30 μV to 300 V f. s. d. in 1-3-10 sequence.
Accuracy:	±5% of full scale.

SELECTIVITY: ±3½ c/s bandwidth, at least 3 dB down,
±20 c/s bandwidth, at least 45 dB down,
±40 c/s bandwidth, at least 63 dB down,
±80 c/s and above, at least 80 dB down.

INTERNAL NOISE & DISTORTION:
Residual hum and noise, and distortion to measured signal at least 80 dB down.

INPUT RESISTANCE: 100 kΩ on maximum attenuator settings between 30 mV and 1 V:
1 MΩ on settings between 3 and 300 V.

RESTORED FREQUENCY OUTPUT

Range:	20 c/s to 50 kc/s.
Output:	Variable up to 1 V r. m. s. out of 600 Ω source, when meter reads f. s. d.

B. F. O. OUTPUT

Range:	20 c/s to 50 kc/s.
Output:	Variable up to 1 V r. m. s. out of 600 Ω source.
Response:	Flat to within ±0.1 dB over frequency range, terminated or unterminated.

RECORDER OUTPUT: 100 μA into 2.5 kΩ. Recorder input to be isolated from ground.

POWER SUPPLY: Any voltage between 190-260 V and 95-130 V a. c.; 45 to 1000 c/s; 4 VA.
OR 18-30 V d. c.; 60 mA; positive earth.

DIMENSIONS & WEIGHT:

Height	*Width*	*Depth*	*Weight*
11 in (28 cm)	18.5 in (47 cm)	11 in (28 cm)	24 lb (11 kg)

Accessories supplied

Shielded Adaptor, type TB 39868 (Greenpar type GE 51002) for converting input or output terminals to a BNC coaxial socket.

Miniature Jack Plug, Rendar type MJP/600, for use in EXT MONITOR socket.

Mains Lead, type MIP 45001, for a. c. operation.

Chapter 2

Operation

2.1 PRELIMINARIES

In order to realize the full measurement accuracy of the wave analyser a preliminary calibration procedure is necessary. This, and the normal measurement techniques, are described in this chapter. Fig. 2.1 summarizes the functions of the controls and the measurement procedures in a form useful for subsequent quick reference.

Power Supply

The analyser may be operated from a.c. mains of a nominal 115 or 230 V, 45 to 1000 c/s; or from a d.c. supply of 18 to 30 V. For a.c. operation the stabilizer allows mains voltages of up to ±20% of the two nominal settings to be used. The instrument is normally dispatched with the 230 V setting unless specified to the contrary. In order to check or change the mains input settings see Section 4.3.

For measurements in the field, the instrument may also be d.c. powered from an external battery of from 18 to 30 V, the approximate current drain being 60 mA.

Fuses

Two fuses are fitted, one in the a.c. mains input circuit, the other in the h.t. supply to the stabilizer. The a.c. input fuses should be 50 mA rating for 230 V operation or 100 mA for 115 V. The other fuse is in circuit for both a.c. and d.c. operation and should be 160 mA rating. Both fuses are 20 x 5 mm; the a.c. input fuse a delay type, the h.t. fuse a quick-blow type.

Switching on

Before switching on:

(1) Check that the mains transformer primary connections are correct for the local supply voltage. If they have to be changed remember that the a.c. input fuse must also be changed.

(2) Set the MAINS/BATTERY slider switch on the rear panel to the position appropriate for the type of supply to be used.

(3) Connect to the power supply.

For a.c. mains use the lead supplied, fitting the small 3 pin plug to the MAINS socket at the rear of the instrument. Initially it will also be necessary to fit a suitable mains supply plug to the lead: note that the earth (or chassis) conductor has a yellow designation sleeve with a green circuit earth symbol, the neutral conductor has a black sleeve with a white 'N' and the line (or phase) conductor has no sleeve.

For d.c., connect the battery to the terminals at the rear of the instrument observing the required polarity; note that the '+' terminal is now connected to chassis. It is also advisable to disconnect the a.c. mains lead.

(4) Check and if necessary adjust the mechanical zero of the meter.

Switch on by turning the SUPPLY switch on the front panel in a clockwise direction. Allow a few minutes for the oscillator to stabilize before zeroing the frequency scale.

(1) SUPPLY switch. Turn clockwise to switch on power supply. A.C. mains or battery power supply may be used, connections and fuses at rear of instrument.

(2) FREQUENCY control. Tune to required signal frequency. Use fine control on panel to give peak meter deflection. Scale is $8\frac{1}{2}$ turn spiral calibrated 0 to 50 kc/s, with zero at outer end. Read scale at position of red marker.

(3) ZERO control. Adjust for peak meter deflection to zero carrier with FUNCTION switch (12) at NORMAL, meter slider switch (10) at VOLTMETER, MAX INPUT switch (7) at 1 V, FREQUENCY scale at zero and no connection to input.

(4) BALANCE MODULATOR presets. Adjust both for minimum meter deflection to suppress carrier after setting carrier zero (3).

(5) SET CALIBRATION preset. Adjust to give full scale (1.0 V) to calibrate meter, with FREQUENCY scale above 20 c/s, VOLTMETER RANGE (8) and FUNCTION (12) switches set to CALIBRATE.

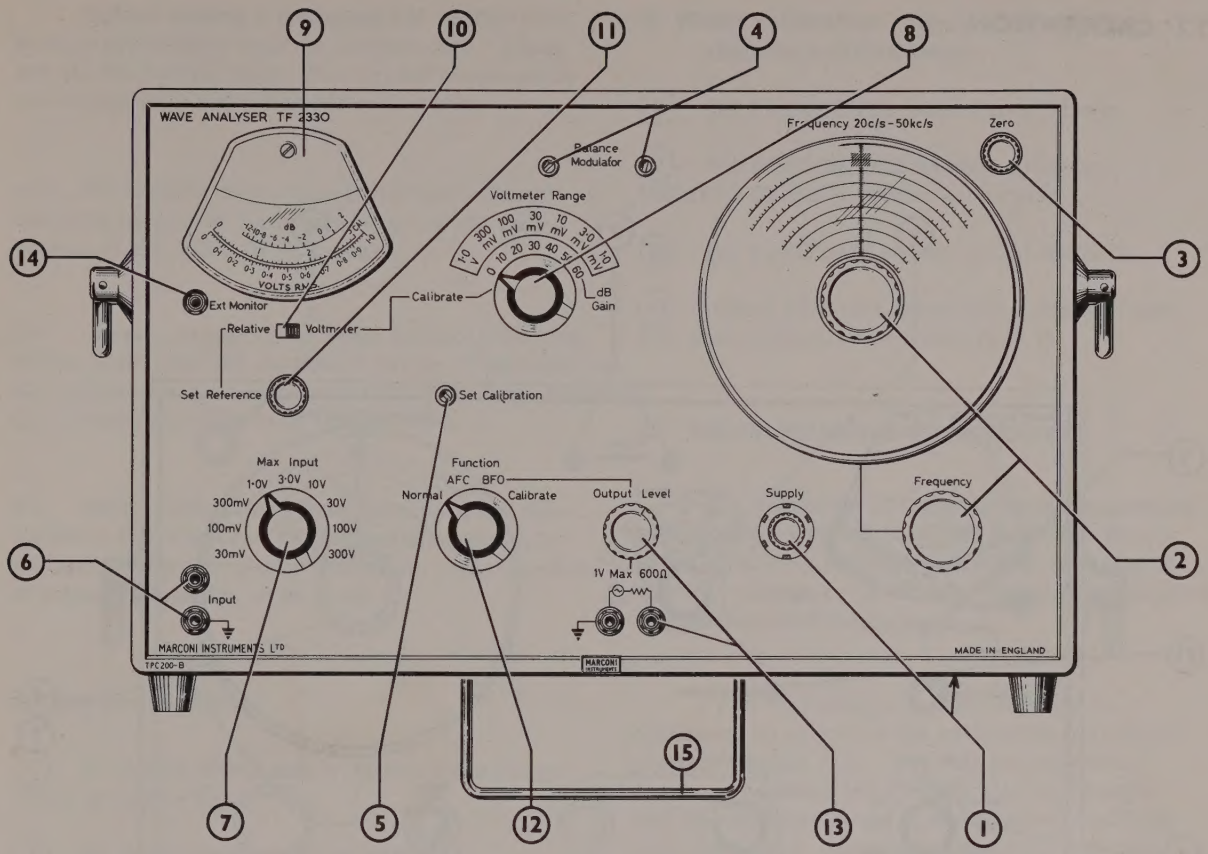


Fig. 2.1 Controls and operational summary

(6) INPUT terminals. Connect signal input 20 c/s to 50 kc/s, maximum voltage 300 V (input stages protected by overload diodes). Use adaptor supplied for conversion to BNC coaxial socket.

(7) MAX INPUT switch. Use input attenuator to set highest meter range for maximum component voltage of input signal.

(8) VOLTMETER RANGE switch. Select range to give convenient meter deflection. Overall coverage of the seven ranges is set by MAX INPUT switch (7).

(9) METER. For absolute voltage measurement calibrate the voltmeter (5) then read voltage from convenient meter scale in conjunction with position of VOLTMETER RANGE switch (8).

(10) RELATIVE/VOLTMETER switch. Set for type of measurement required. RELATIVE for comparison of levels, VOLTMETER for absolute voltage measurement.

(11) SET REFERENCE control. Level of input signal may be adjusted for relative measurements to give convenient meter deflection (0 dB or 1.0) as datum for fundamental component.

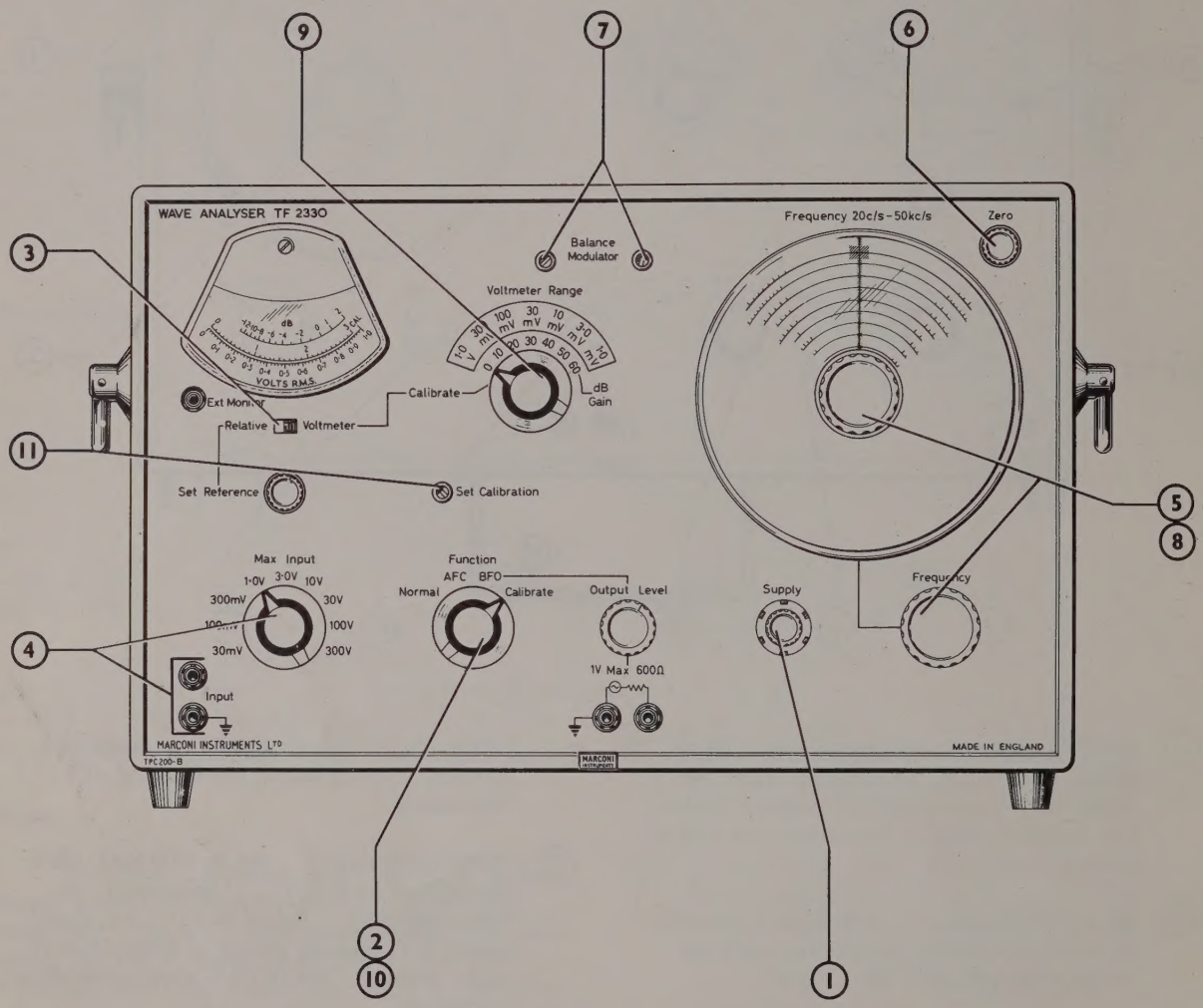
(12) FUNCTION switch. Set to NORMAL while tuning then to A. F. C., if necessary, for measurements. Select B. F. O. for signal output at frequency shown by FREQUENCY scale setting. Set to CAL when calibrating voltmeter.

(13) SIGNAL OUTPUT. Variable up to 1 V across 600 Ω. On NORMAL and A. F. C. positions the restored output has the same frequency as the input signal component to which the analyser is tuned. On B. F. O. position, an output of 20 c/s to 50 kc/s set by FREQUENCY control, is available for use as a signal source. Use adaptor supplied to convert terminals to BNC coaxial socket.

(14) EXT MONITOR socket. Output of 100 μA into 2.5 kΩ available for external recorder having input isolated from ground.

(15) SUPPORT. Hinges down to raise front of instrument.

2.2 CALIBRATION



Note: During the initial calibration procedure you may notice considerable instability of the meter reading. This is only present when the FREQUENCY dial is set to zero (owing to the fact that noise in transistors is proportional to the inverse of frequency) and has no effect on actual measurements.

Before making a measurement certain calibration procedures must be carried out. These are (a) Set carrier zero, (b) Carrier suppression (in modulator), and (c) Meter calibration.

(a) Set carrier zero - this procedure adjusts the local oscillator frequency to set up the calibration of the FREQUENCY scale.

(b) Carrier suppression - this balances the ring bridge modulator for maximum carrier suppression, the degree of suppression required depending upon the the lowest frequency to be investigated.

(c) Meter calibration - this calibrates the voltmeter at 1.0 V against an internal standard voltage and is only necessary if absolute measurements of signal voltage are to be made.

(a) Set carrier zero

(1) Switch on power supply, allow 2-3 minutes warm up before (6).

(2) Set FUNCTION switch to NORMAL.

(3) Set meter slider switch to VOLTMETER.

(4) Set MAX INPUT switch to 1.0 V or above and ensure no input connected.

(5) Set FREQUENCY scale to zero (outer end of spiral).

(6) Adjust ZERO control for maximum meter reading, using VOLTMETER RANGE switch to give convenient deflection.

(b) Carrier suppression

After having set carrier zero:

(7) Adjust BALANCE MODULATOR controls for minimum meter reading; the controls are interacting. The degree of suppression necessary depends upon the lowest subsequent measurement frequency:

For 100 c/s suppress down to 30 dB.

For 20 c/s suppress down to 40 dB.

(c) Meter calibration (only necessary for absolute measurements).

(8) Set FREQUENCY scale above 20 c/s.

(9) Set VOLTMETER RANGE switch to CALIBRATE (fully counter-clockwise).

(10) Set FUNCTION switch to CALIBRATE.

(11) Adjust SET CALIBRATION control to give full scale deflection on meter (1.0 V).

2.3 MEASUREMENT PROCEDURES

The amplitude of the component frequencies of a complex waveform, within the range 20 c/s to 50 kc/s, may be measured either in terms of absolute voltage or in decibels and percent relative to a fundamental datum level.

Prior to making a measurement it is necessary to carry out the calibration procedure given in Section 2.2. For full measurement accuracy with low level inputs also make sure that the analyser is not in a strong external magnetic hum field, especially when rack mounted.

In order to obtain consistent measurement accuracy an a.f.c. facility is included. When the analyser has been tuned to the signal under test the a.f.c. circuit will allow it to follow frequency variations of up to 100 c/s. This avoids the necessity for continual retuning when investigating a signal from a source that is prone to drift or where adjustments being made to the source tend to pull the output frequency.

Reading the meter

The instrument is calibrated in volts and decibels. Fig. 2.2 shows how the two attenuators are interconnected to give a relative measurement range of 10^4 V in an overall input range of 10^8 V. The meter has two voltage scales, 0 to 1.0 and 0 to 3, the reading being taken from the scale appropriate to the setting of the VOLTMETER RANGE switch, which provides the full scale multiplying factor. These two scales may also be used to obtain relative measurements in terms of percent, by reading the 0 to 1.0 scale as 0 to 100%, and the 0 to 3 scale as 0 to 30% after having set the meter reading for the fundamental to be 100% by means of the SET REFERENCE control.

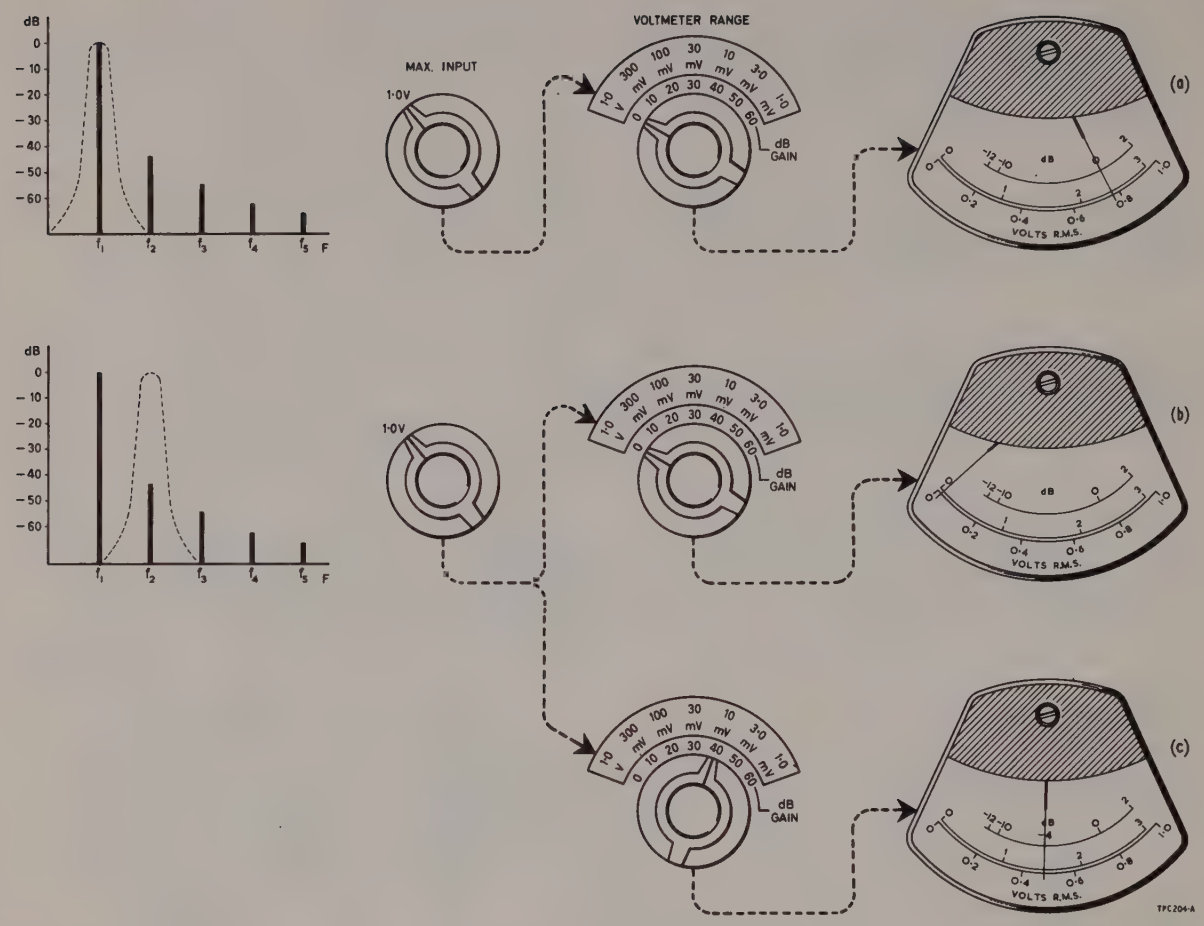


Fig. 2.2 Measurement system

Decibel calibration is in dBm, i.e. referred to 1 mW in 600 Ω, 0 dBm corresponding to 0.775 V. The meter scale covers the range -13 to +2 dB. The VOLTMETER RANGE switch, calibrated in terms of meter amplifier gain, provides a further six 10 dB steps giving a total coverage of -73 to +2 dB. To obtain a reading in dB's, subtract the VOLTMETER RANGE switch decade from the meter indication. If the fundamental amplitude has been set to 0 dB then the reading obtained will be the number of dB's the particular component is below the fundamental. The example shown in Fig. 2.2 has a second harmonic, f_2, which is 44 dB down: however, had the meter indication been f.s.d., the resultant reading would be 2-40 = -38 dB, i.e., 38 dB down.

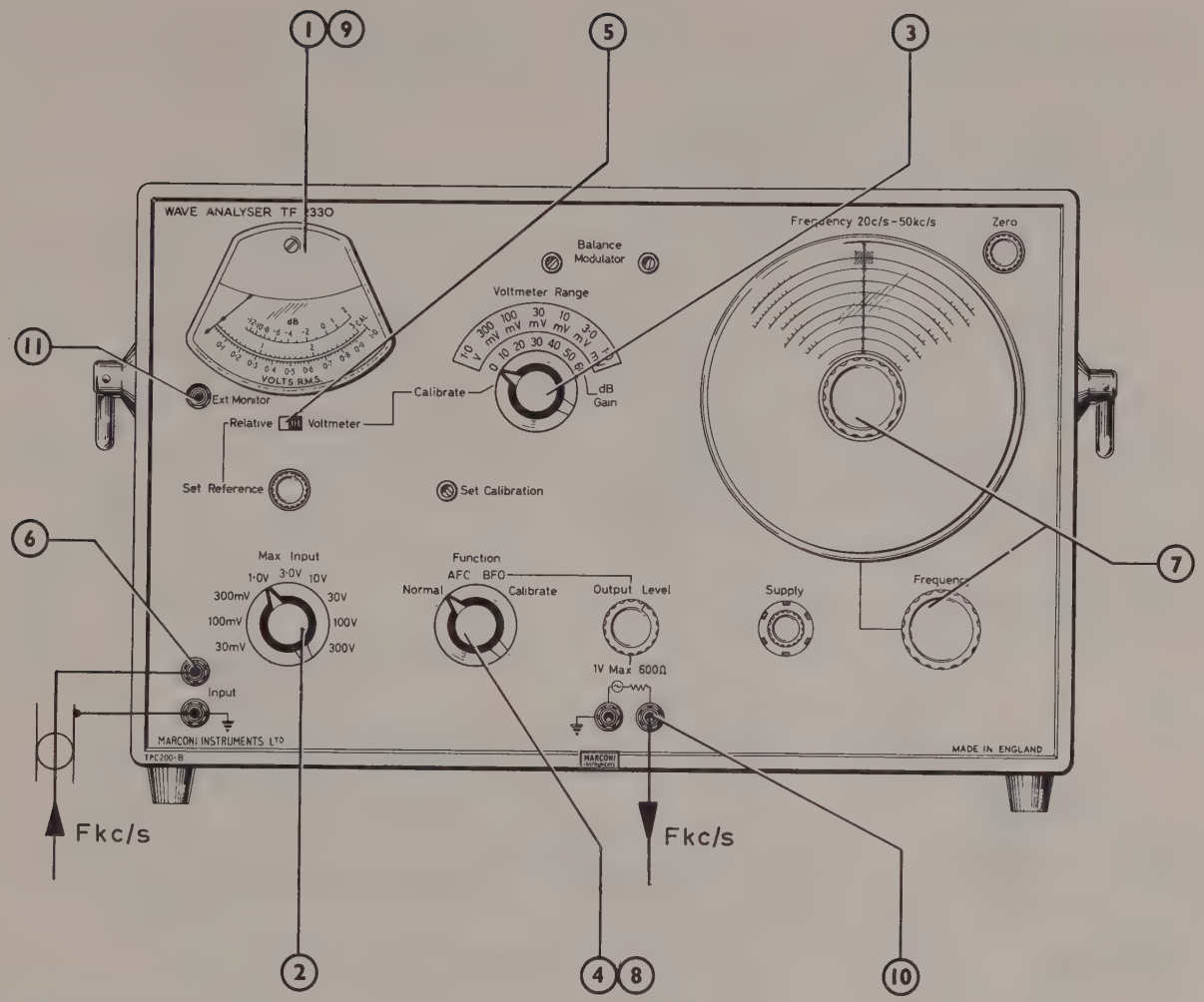
Absolute measurements

The absolute amplitude of any component of a waveform may be determined by the following procedure. The measurement may be made in volts, or in dBm where the signal is derived from a source having a terminating impedance of 600 Ω. The difference in amplitude between individual components of a waveform from any other source may be measured in dB's by algebraically subtracting the readings obtained for each component.

A harmonic analysis of a waveform can be carried out using absolute measurements though relative measurements are usually more convenient. The procedure is simplified if the signal level can be adjusted externally for setting the fundamental datum.

(1) Calibrate instrument as detailed in Section 2.2.

(2) Set MAX INPUT switch to nearest range above expected signal level or to suitably higher range if level is unknown.



(3) Set VOLTMETER RANGE switch to 0 dB (fully counter-clockwise).

(4) Set FUNCTION switch to NORMAL.

(5) Set meter slider switch to VOLTMETER.

(6) Connect signal to INPUT terminals. Use adaptor supplied for conversion to BNC coaxial socket.

(7) Tune for peak meter reading at signal component frequency. If meter deflection is below -10 dB set MAX INPUT switch to next lower range. When comparing several component amplitudes set MAX INPUT switch for highest then adjust VOLTMETER RANGE to give convenient deflection for others.

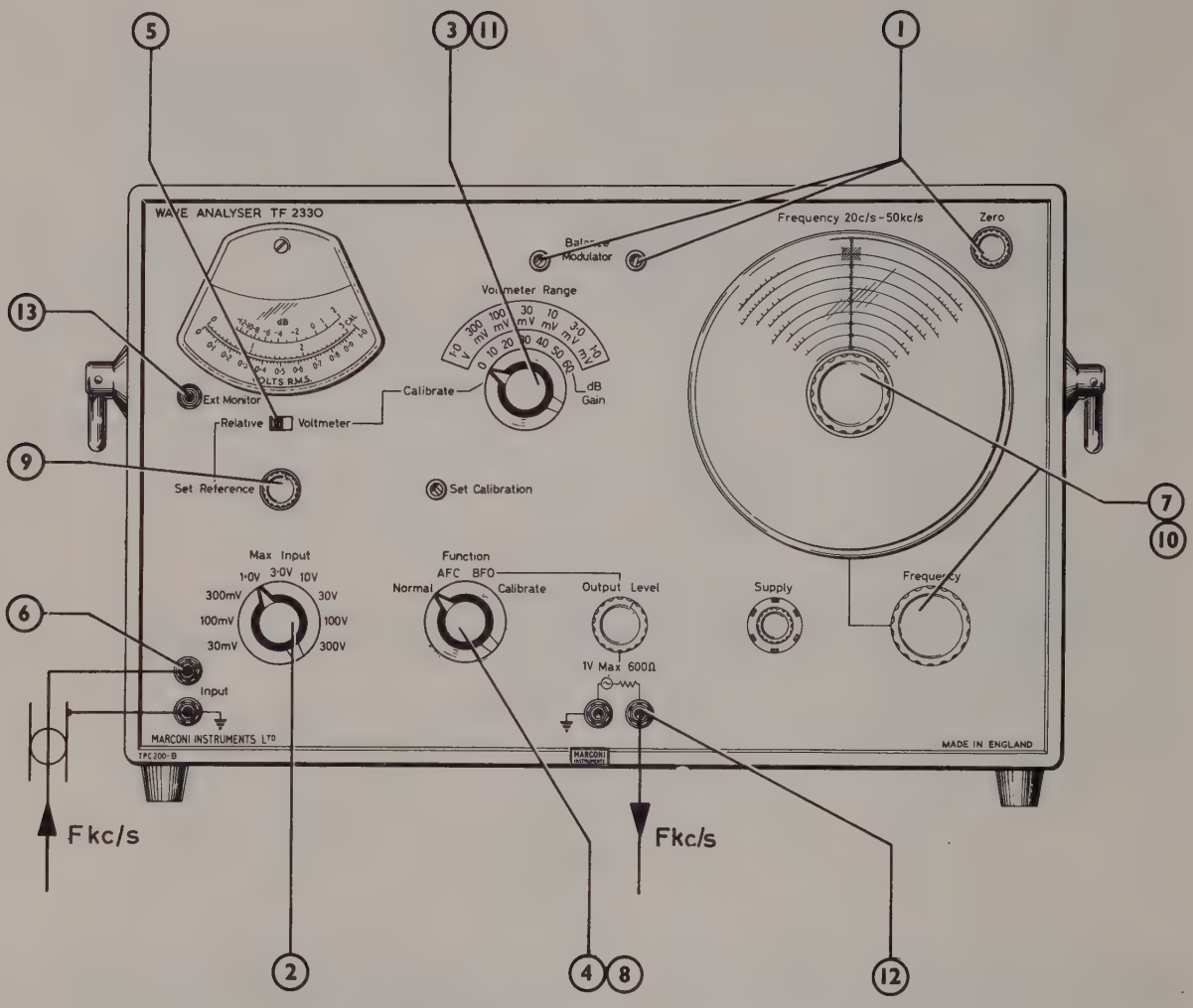
(8) Set FUNCTION switch to A. F. C.

(9) Read amplitude of signal component in conjunction with setting of VOLTMETER RANGE switch.

(10) Output of up to 1 V available at frequency of component to which analyser is tuned; see Section 2.4.

(11) External monitor may be connected in series with meter; see Section 2.4.

Relative measurements



An analysis of a waveform may be obtained by measuring the amplitudes of the harmonic and noise components relative to that of the fundamental frequency component. The measurements may be made in terms of decibels or percent.

For relative measurements the signal in the input amplifier may be adjusted by means of the SET REFERENCE control in order to set the fundamental component to a convenient datum level. Since all other measurements on the waveform are then made with reference to this datum it is not necessary for the voltmeter calibration to be absolute.

(1) Carry out relevant calibration procedure as detailed in Section 2.2.

(2) Set MAX INPUT switch to nearest range above expected level of fundamental or to suitably higher range if level unknown.

(3) Set VOLTMETER RANGE switch to 0 dB (fully counter-clockwise).

(4) Set FUNCTION switch to NORMAL.

(5) Set meter slider switch to RELATIVE.

(6) Connect signal to INPUT terminals.

(7) Tune initially for peak meter deflection at fundamental frequency.

(8) Set FUNCTION switch to A. F. C.

(9) Adjust SET REFERENCE control and, if necessary, MAX INPUT switch in order to set meter pointer to 0 dB or 1.0 V (100%) as required.

(10) Tune to harmonic.

(11) Adjust VOLTMETER RANGE switch to give convenient meter deflection; DO NOT ALTER MAX INPUT SWITCH SETTING. Read harmonic amplitude from meter in conjunction with setting of VOLTMETER RANGE switch.

(12) Output of up to 1 V available at frequency of component to which the analyser is tuned; see Section 2.4.

(13) External monitor may be connected in series with meter; see Section 2.4.

2.4 SIGNAL OUTPUTS

Two a.c. signal outputs are available at a pair of front panel terminals. The first is derived from the input waveform component to which the analyser is tuned, the second is generated internally to provide a useful signal source. Both outputs are developed across 600 Ω and are continuously variable up to 1 V.

A d.c. output is available at the EXT MONITOR socket where an external recorder may be connected in series with the meter.

Restored frequency output

This output is so called because the 100 kc/s i.f. signal derived from the input frequency component is recombined with the local oscillator output to provide a signal whose frequency is restored to that of the original input. The output voltage is highest at full scale deflection on the meter, and the waveform is sinusoidal but includes above 5% distortion.

When the analyser is being used to investigate a complex waveform having components that are not harmonically connected to any known fundamental the restored frequency output may be applied to an external frequency meter in order to ascertain the frequency of such a component with greater accuracy than is possible with the analyser. For this measurement the FUNCTION switch should be set to A.F.C. to ensure that the analyser is kept tuned to the component.

B.F.O. output

For this facility the output from a supplementary internal oscillator is combined with that of the local oscillator to provide a b.f.o. signal source tuned by and in step with the voltmeter tuning over the normal range of 20 c/s to 50 kc/s. When the signal level has been set, using the OUTPUT LEVEL control, it will remain constant within 0.1 dB over the whole frequency range.

External monitor

The EXT MONITOR socket, situated adjacent to the meter, is connected in series with it. The d.c. flowing through the meter at any time may be used to energize a recorder so that a permanent record of an analysis can be made. The current for f.s.d. is 100 μA into a resistance of up to 2.5 kΩ; the recorder input must be isolated from ground and connection should be made with the jack plug provided which is a Rendar type MJP/600.

2.5 APPLICATIONS

The wave analyser is basically a highly selective and sensitive tuned voltmeter. The main application, therefore, is the measurement of individual components of a waveform whether they are harmonically related or not, for example the spurious products of modulation or noise. The ability to measure voltages as low as 3 μV, aided by the a.f.c. facility, enables a comprehensive analysis to be made of any a.f. signal.

The other main feature is the internal b.f.o. facility which may be used as a stable energizing source of a.f. either in conjunction with the tuned voltmeter section of the instrument or on its own.

Frequency spectrum

A frequency spectrum of the output signal from an audio frequency device may be obtained by slowly tuning through the frequency range of the analyser and noting the amplitude of each frequency component of the signal. If the device under investigation is generating the output itself the results will probably be required referred to a fundamental frequency. The amplitude measurements may therefore be made either in absolute or relative terms.

If the device has to be energized from an external source, such as is the case with filters and amplifiers, it is important to ensure that no harmonics are present in the input to the device.

This is necessary because phase differences between the harmonics in the input and those introduced by the device will give rise to erroneous measurements of harmonic amplitudes. Therefore, use either a low distortion source or include a low pass filter between the source and the device.

Harmonic distortion

The distortion present in a waveform may be expressed as individual harmonics, each given as a percentage of the fundamental or as a ratio in decibels. These measurements may be made in absolute or relative terms by tuning to the fundamental and then to each successive harmonic. Remember that mains supply hum components may also be of significant proportions; if so, these should be included.

An alternative way of expressing the distortion is as a total percentage distortion factor for the waveform. This may be obtained by substituting the appropriate values in one of the following expressions.

(a) The total percentage distortion is given by

$$D\% = \frac{\sqrt{(V_2^2 + V_3^2 + \ldots\ldots V_{H1}^2 + V_{H2}^2 + ..)}}{V_1} \times 100$$

where V_1 is the amplitude of the fundamental.

V_2, V_3, etc., are the amplitudes of the individual harmonic components.

V_{H1}, V_{H2}, etc., are the amplitudes of the hum components.

The values of V_1, V_2, etc., may be absolute or relative measurements in volts or decibels.

(b) When the amplitude of each distortion component is less than 10 to 15% a negligible error results from using

$$D\% = \sqrt{\frac{(V_2^2 + V_3^2 + \ldots\ldots V_{H1}^2 + V_{H2}^2 + ..)}{(V_1^2 + V_2^2 + V_3^2 \ldots V_{H1}^2 + V_{H2}^2 + ..)}} \times 100$$

This expression gives the same value for D as would normally be obtained by a distortion factor meter.

When V_2, V_{H1}, etc., are measured as percentages of the fundamental the expression simplifies to

$$D\% = \sqrt{(V_2^2 + V_3^2 + \ldots\ldots V_{H1}^2 + V_{H2}^2 + ..)}$$

(c) If the distortion components levels are measured in absolute dBm or relative dB use

$$D\% = \sqrt{\left(\frac{V_2}{V_1}\right)^2 + \left(\frac{V_3}{V_1}\right)^2 + \ldots \left(\frac{V_{H1}}{V_1}\right)^2 + \left(\frac{V_{H2}}{V_1}\right)^2 + ..} \times 100$$

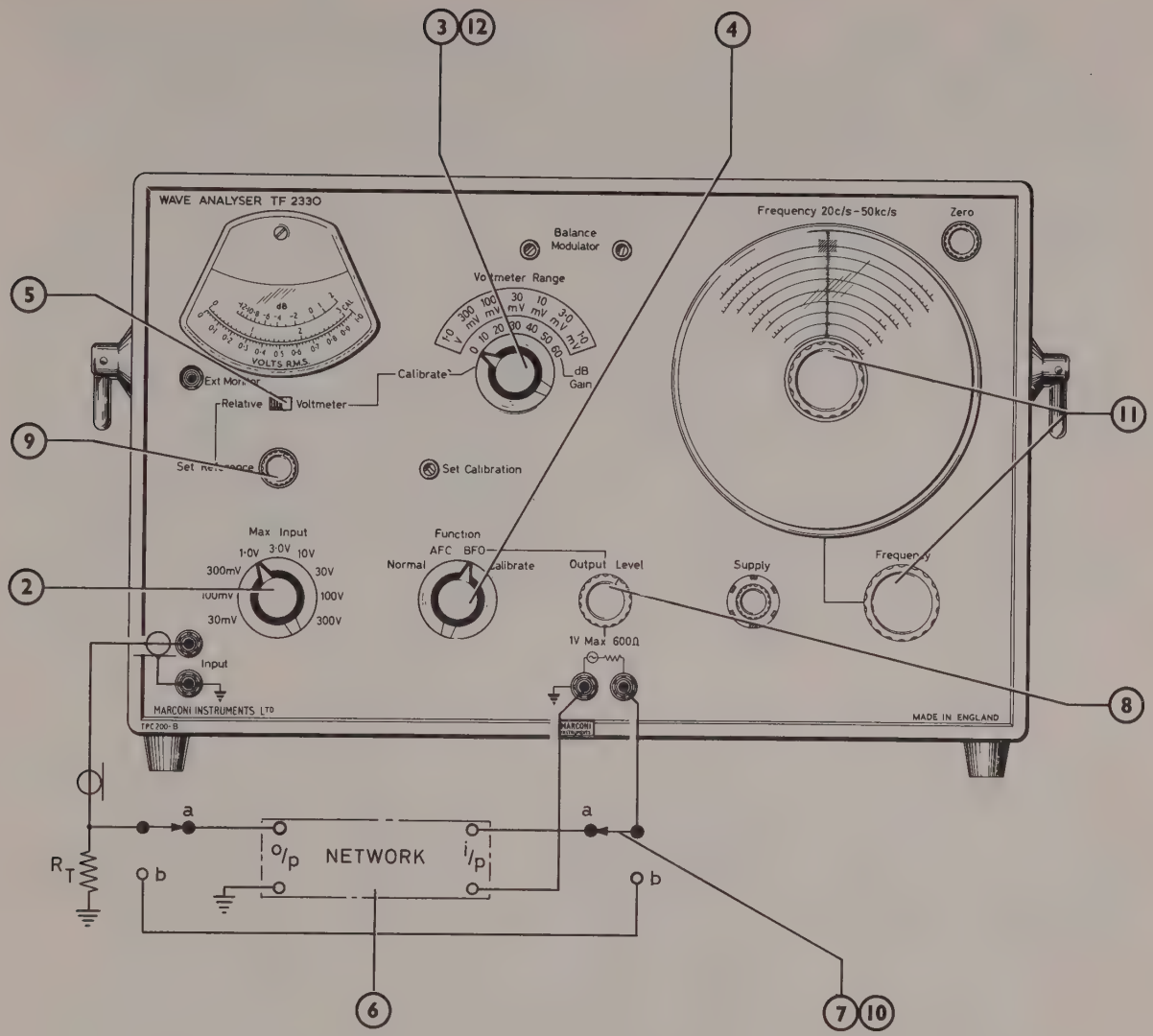
where the ratios $\frac{V_2}{V_1}, \frac{V_{H1}}{V_1}$, etc., are obtained from the Decibel Conversion Table at the end of this chapter, for the number of decibels each component is down on the fundamental.

Frequency response

By using the b. f. o. output as the signal source and the tuned voltmeter as the monitor, frequency responses of networks may be easily determined over the range 20 c/s to 50 kc/s. Since the b. f. o. output is derived from the internal local oscillator its frequency will automatically be in step with voltmeter tuning, also its level stability is of a similar high order.

For the response of a network such as a filter, where the required measurement is the variation in output with frequency relative to a given input, a terminating resistor, R_T, must be included. It should be equal in value to the characteristic impedance of the filter so that when setting the signal datum level the circuit impedance remains the same as when the filter is connected. For the response of an amplifier the measurement will be the variation in output with frequency relative to the output as an arbitrary centre frequency so that the network switching shown will not be required. However, the amplifier should be terminated with its normal working load.

If a test voltage of considerably less than 1 V is required connect a potential divider between the OUTPUT terminals and the network.



(1) Calibrate instrument as detailed in Section 2.2.

(2) Set MAX INPUT switch to 1.0 V.

(3) Set VOLTMETER RANGE switch to 0 dB.

(4) Set FUNCTION switch to B. F. O.

(5) Set meter slider switch to RELATIVE.

(6) Connect network under test to B. F. O. OUTPUT and INPUT terminals. Use adaptor supplied to convert terminals to BNC coaxial socket. Value of R_T should be the same as the characteristic impedance of network. Incorporate potential divider for low test voltages.

(7) Set NETWORK switch to 'b' position.

(8) Adjust OUTPUT LEVEL and SET (9) REFERENCE controls for datum signal level (0 dB or 100% on meter).

(10) Set Network switch to 'a' position.

(11) Tune FREQUENCY control over required (12) range, adjusting VOLTMETER RANGE switch to give convenient meter deflection at selected frequencies. Do not alter setting of (8) or (9).

Alternatively, when measuring frequency response of, say, an amplifier, set datum level at convenient mid-frequency (1 kc/s) keeping Network switch at 'a' position.

Intermodulation distortion

Any non-linearity in an amplifier will give rise to distortion in its output. When the input to the amplifier is a simple sinewave this distortion will be in the form of harmonics and may be easily assessed by a normal harmonic analysis of the output waveform. However, when the input is a complex multi-frequency waveform certain frequency components of the waveform may interact giving rise to intermodulation distortion. Here the non-linearity causes amplitude modulation of one frequency component by another strong component. By measuring the modulation components resulting from the application of two suitable frequencies to an amplifier this distortion may be determined.

If the degree of non-linearity is uniform throughout the whole frequency range any of the distortion measurements will give equivalent results. However, if the non-linearity is worse at one or other end of the frequency range, the appropriate intermodulation distortion measurement will give a better assessment of the non-linearity than a simple harmonic analysis.

Two methods that may be used for the measurement of intermodulation distortion in an amplifier are given below, one method giving the distortion due to non-linearity at the lower end of the frequency range, the second giving that at the upper end. In each method the two test signals are applied to the amplifier under test via an adding network, which may take the form of a centre tapped transformer or a bridge configuration of resistors. This is to ensure that the two signals are not cross modulated before reaching the amplifier. To avoid overloading the input stages

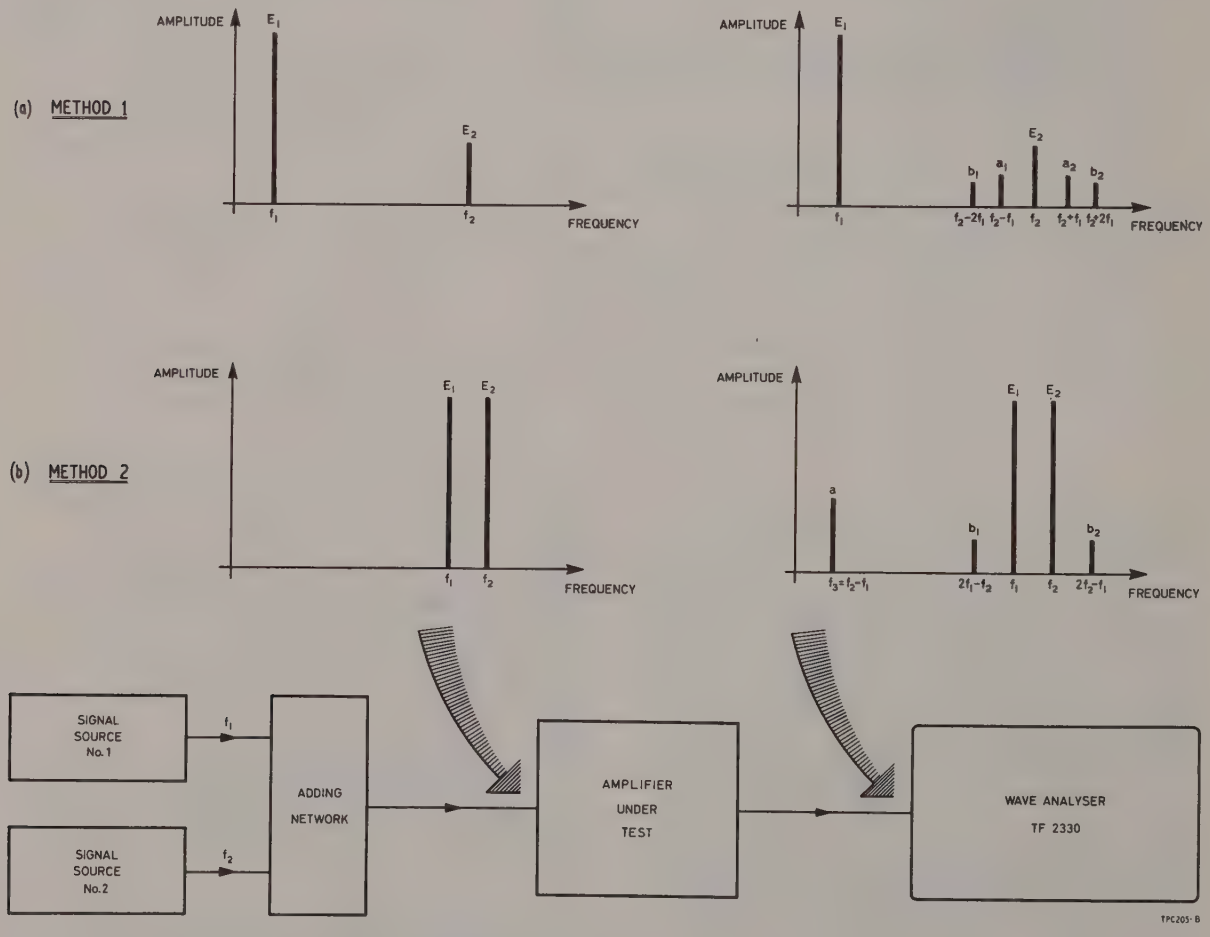


Fig. 2.3 Measurement of intermodulation distortion

the peak sum of all input signals should not exceed 1.4 x meter f. s. d.

Method 1

This method gives a measure of the distortion due to the effect of low frequencies on high frequencies, caused by non-linearity at the low frequency end.

The two test frequencies f_1 and f_2, shown in Fig. 2.3 (a), should be chosen so that f_1 and the higher modulation components come within the bandwidth of the amplifier, otherwise the falling response at the extremes of the bandwidth will attenuate the true amplitudes of these components. The amplitude of the lower frequency E_1, should be four times that of the other E_2. The relative amplitudes of the modulation components a_1, a_2, b_1, b_2, etc., may be measured in voltage or percent, the intermodulation distortion being given by

$$\text{I. D.\%} = \frac{\sqrt{(a_1 + a_2)^2 + (b_1 + b_2)^2 + \ldots}}{E_2} \times 100$$

or when E_2 is set as 100% this simplifies to

$$\text{I. D.\%} = \sqrt{(a_1 + a_2)^2 + (b_1 + b_2)^2 + \ldots}$$

Method 2

This method gives a measure of low frequency distortion components produced by high frequencies due to non-linearity at the high frequency end.

The two test frequencies, f_1 and f_2, shown in Fig. 2.3 (b), should be chosen so that they are near the upper end of the bandwidth while their difference frequency, f_3, is near the lower end, being between 50 and 200 c/s. The amplitudes of f_1 and f_2, E_1 and E_2 respectively, should be equal and the intermodulation distortion is given by

$$\text{I. D.\%} = \frac{a}{E_1 + E_2} \times 100$$

where a is the amplitude of f_3.

If the levels of both E_1 and E_2 are set as 50% this simplifies to

$$\text{I. D.\%} = a.$$

The above expression gives equivalent results to those that would be obtained by using the standard measurement method of filtering out the fundamental components and measuring the second order term 'a'. This method, however, neglects the third order terms b_1 and b_2 which should also be investigated.

DECIBEL CONVERSION TABLE

Ratio Down			Ratio Up	
VOLTAGE	POWER	DECIBELS	VOLTAGE	POWER
1·0	1·0	**0**	1·0	1·0
·9886	·9772	**·1**	1·012	1·023
·9772	·9550	**·2**	1·023	1·047
·9661	·9333	**·3**	1·035	1·072
·9550	·9120	**·4**	1·047	1·096
·9441	·8913	**·5**	1·059	1·122
·9333	·8710	**·6**	1·072	1·148
·9226	·8511	**·7**	1·084	1·175
·9120	·8318	**·8**	1·096	1·202
·9016	·8128	**·9**	1·109	1·230
·8913	·7943	**1·0**	1·122	1·259
·8710	·7586	**1·2**	1·148	1·318
·8511	·7244	**1·4**	1·175	1·380
·8318	·6918	**1·6**	1·202	1·445
·8128	·6607	**1·8**	1·230	1·514
·7943	·6310	**2·0**	1·259	1·585
·7762	·6026	**2·2**	1·288	1·660
·7586	·5754	**2·4**	1·318	1·738
·7413	·5495	**2·6**	1·349	1·820
·7244	·5248	**2·8**	1·380	1·905
·7079	·5012	**3·0**	1·413	1·995
·6683	·4467	**3·5**	1·496	2·239
·6310	·3981	**4·0**	1·585	2·512
·5957	·3548	**4·5**	1·679	2·818
·5623	·3162	**5·0**	1·778	3·162
·5309	·2818	**5·5**	1·884	3·548
·5012	·2512	**6**	1·995	3·981
·4467	·1995	**7**	2·239	5·012
·3981	·1585	**8**	2·512	6·310
·3548	·1259	**9**	2·818	7·943
·3162	·1000	**10**	3·162	10·000
·2818	·07943	**11**	3·548	12·59
·2512	·06310	**12**	3·981	15·85
·2239	·05012	**13**	4·467	19·95
·1995	·03981	**14**	5·012	25·12
·1778	·03162	**15**	5·623	31·62

DECIBEL CONVERSION TABLE (continued)

Ratio Down			Ratio Up	
VOLTAGE	POWER	DECIBELS	VOLTAGE	POWER
·1585	·02512	**16**	6·310	39·81
·1413	·01995	**17**	7·079	50·12
·1259	·01585	**18**	7·943	63·10
·1122	·01259	**19**	8·913	79·43
·1000	·01000	**20**	10·000	100·00
·07943	$6{\cdot}310 \times 10^{-3}$	**22**	12·59	158·5
·06310	$3{\cdot}981 \times 10^{-3}$	**24**	15·85	251·2
·05012	$2{\cdot}512 \times 10^{-3}$	**26**	19·95	398·1
·03981	$1{\cdot}585 \times 10^{-3}$	**28**	25·12	631·0
·03162	$1{\cdot}000 \times 10^{-3}$	**30**	31·62	1,000
·02512	$6{\cdot}310 \times 10^{-4}$	**32**	39·81	$1{\cdot}585 \times 10^{3}$
·01995	$3{\cdot}981 \times 10^{-4}$	**34**	50·12	$2{\cdot}512 \times 10^{3}$
·01585	$2{\cdot}512 \times 10^{-4}$	**36**	63·10	$3{\cdot}981 \times 10^{3}$
·01259	$1{\cdot}585 \times 10^{-4}$	**38**	79·43	$6{\cdot}310 \times 10^{3}$
·01000	$1{\cdot}000 \times 10^{-4}$	**40**	100·00	$1{\cdot}000 \times 10^{4}$
$7{\cdot}943 \times 10^{-3}$	$6{\cdot}310 \times 10^{-5}$	**42**	125·9	$1{\cdot}585 \times 10^{4}$
$6{\cdot}310 \times 10^{-3}$	$3{\cdot}981 \times 10^{-5}$	**44**	158·5	$2{\cdot}512 \times 10^{4}$
$5{\cdot}012 \times 10^{-3}$	$2{\cdot}512 \times 10^{-5}$	**46**	199·5	$3{\cdot}981 \times 10^{4}$
$3{\cdot}981 \times 10^{-3}$	$1{\cdot}585 \times 10^{-5}$	**48**	251·2	$6{\cdot}310 \times 10^{4}$
$3{\cdot}162 \times 10^{-3}$	$1{\cdot}000 \times 10^{-5}$	**50**	316·2	$1{\cdot}000 \times 10^{5}$
$2{\cdot}512 \times 10^{-3}$	$6{\cdot}310 \times 10^{-6}$	**52**	398·1	$1{\cdot}585 \times 10^{5}$
$1{\cdot}995 \times 10^{-3}$	$3{\cdot}981 \times 10^{-6}$	**54**	501·2	$2{\cdot}512 \times 10^{5}$
$1{\cdot}585 \times 10^{-3}$	$2{\cdot}512 \times 10^{-6}$	**56**	631·0	$3{\cdot}981 \times 10^{5}$
$1{\cdot}259 \times 10^{-3}$	$1{\cdot}585 \times 10^{-6}$	**58**	794·3	$6{\cdot}310 \times 10^{5}$
$1{\cdot}000 \times 10^{-3}$	$1{\cdot}000 \times 10^{-6}$	**60**	1,000	$1{\cdot}000 \times 10^{6}$
$5{\cdot}623 \times 10^{-4}$	$3{\cdot}162 \times 10^{-7}$	**65**	$1{\cdot}778 \times 10^{3}$	$3{\cdot}162 \times 10^{6}$
$3{\cdot}162 \times 10^{-4}$	$1{\cdot}000 \times 10^{-7}$	**70**	$3{\cdot}162 \times 10^{3}$	$1{\cdot}000 \times 10^{7}$
$1{\cdot}778 \times 10^{-4}$	$3{\cdot}162 \times 10^{-8}$	**75**	$5{\cdot}623 \times 10^{3}$	$3{\cdot}162 \times 10^{7}$
$1{\cdot}000 \times 10^{-4}$	$1{\cdot}000 \times 10^{-8}$	**80**	$1{\cdot}000 \times 10^{4}$	$1{\cdot}000 \times 10^{8}$
$5{\cdot}623 \times 10^{-5}$	$3{\cdot}162 \times 10^{-9}$	**85**	$1{\cdot}778 \times 10^{4}$	$3{\cdot}162 \times 10^{8}$
$3{\cdot}162 \times 10^{-5}$	$1{\cdot}000 \times 10^{-9}$	**90**	$3{\cdot}162 \times 10^{4}$	$1{\cdot}000 \times 10^{9}$
$1{\cdot}000 \times 10^{-5}$	$1{\cdot}000 \times 10^{-10}$	**100**	$1{\cdot}000 \times 10^{5}$	$1{\cdot}000 \times 10^{10}$
$3{\cdot}162 \times 10^{-6}$	$1{\cdot}000 \times 10^{-11}$	**110**	$3{\cdot}162 \times 10^{5}$	$1{\cdot}000 \times 10^{11}$
$1{\cdot}000 \times 10^{-6}$	$1{\cdot}000 \times 10^{-12}$	**120**	$1{\cdot}000 \times 10^{6}$	$1{\cdot}000 \times 10^{12}$
$3{\cdot}162 \times 10^{-7}$	$1{\cdot}000 \times 10^{-13}$	**130**	$3{\cdot}162 \times 10^{6}$	$1{\cdot}000 \times 10^{13}$
$1{\cdot}000 \times 10^{-7}$	$1{\cdot}000 \times 10^{-14}$	**140**	$1{\cdot}000 \times 10^{7}$	$1{\cdot}000 \times 10^{14}$

Chapter 3

Technical description

The following functional description should be read in conjunction with the circuit diagrams included at the end of this manual. Section 3.1 outlines the main electrical and mechanical features of the instrument while section 3.2 gives a more detailed account of the electrical circuits used therein.

3.1 GENERAL

This wave analyser is basically a super-heterodyne receiver covering the range 20 c/s to 50 kc/s with an i.f. of 100 kc/s. The input signal is fed via an attenuator (the MAX INPUT control) to an input amplifier. The signal then passes through a low pass filter to a ring bridge modulator. The filter stops any 100 kc/s component in the input from reaching the i.f. amplifier stages.

The input signal is mixed with the output of a variable frequency local oscillator, range 100 to 150 kc/s, in the ring bridge with a carrier rejection better than 80 dB. The difference frequency signal from the ring bridge is fed to the first part of a crystal filter having a 7 c/s pass band. This 100 kc/s signal is then amplified and passed to the i.f. attenuator (the VOLTMETER RANGE control) which is an accurate ladder network having six 10 dB steps.

The output from the attenuator goes to the second part of the crystal filter and another amplifier stage. This is followed by the main i.f. amplifier which has adjustable gain, set by the SET CALIBRATION control.

The i.f. output is fed to the meter amplifier and rectifier circuit. A linear meter scale is

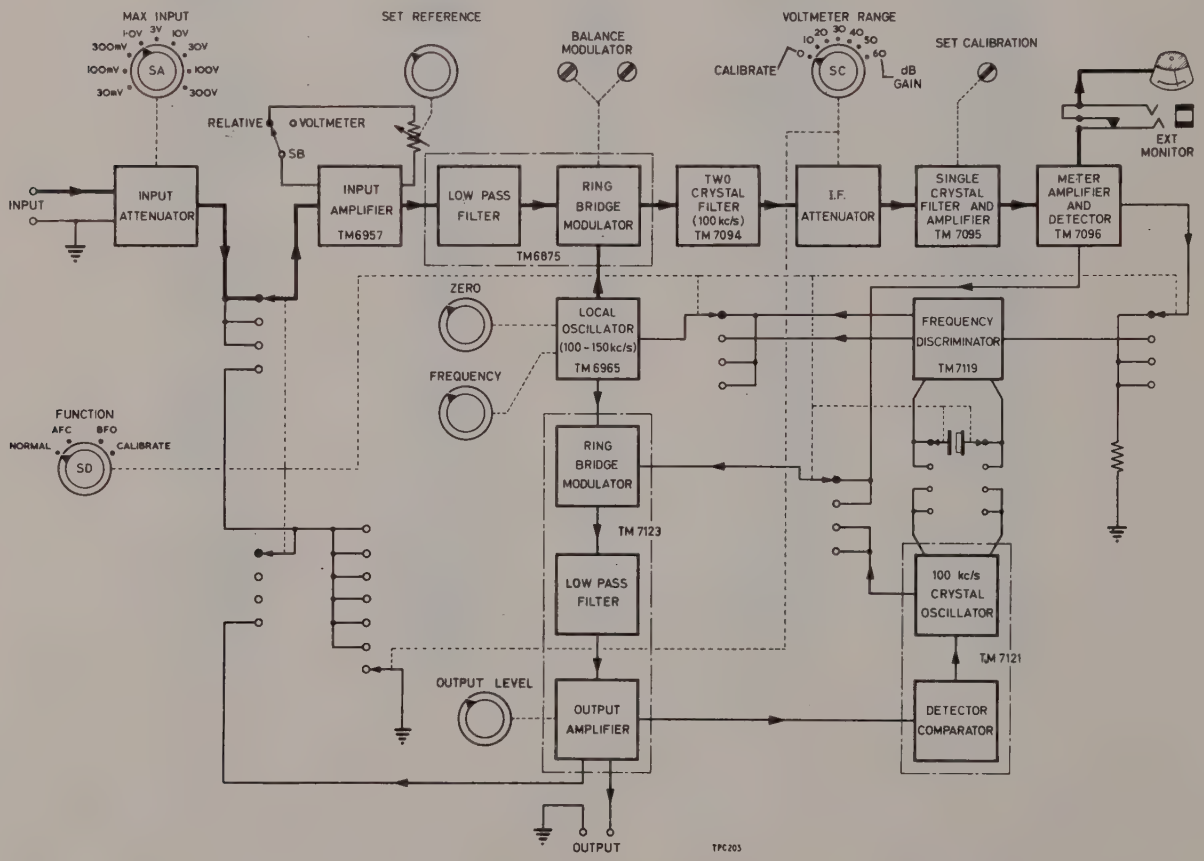


Fig. 3.1 Block diagram

obtained by having the rectifier circuit in the negative feedback loop of the amplifier. A separate output from the meter amplifier is used for a.f.c. purposes and when remixed with the local oscillator output provides the restored frequency output.

Permeability tuning is used for the local oscillator with padder and trimmer inductances in the tuned circuit to enable the frequency law to be adjusted for a precalibrated frequency scale. A crystal discriminator provides the a.f.c. signal which is applied to a voltage variable capacitor included in the tuned circuit.

A restored frequency output is derived by combining the i.f. signal with the local oscillator output in another ring bridge modulator. The difference frequency, being that of the original input signal, is filtered and amplified before being fed to the output terminals via the OUTPUT LEVEL control.

A b.f.o. output is similarly derived by combining the output from a separate 100 kc/s crystal oscillator with the local oscillator output. A signal taken from the output amplifier via a detector comparator provides an error signal which is added to the feedback of the 100 kc/s oscillator to control its amplitude. This results in a signal of very stable output level, a feature which is utilized by also making it the calibration reference used when setting up the gain of the voltmeter section. A relay is used to switch the reference signal to the input amplifier, located remote from the high signal levels associated with the b.f.o. circuit in order to prevent 100 kc/s breakthrough. The same 100 kc/s crystal is used for both the discriminator and the oscillator as the two circuits are not used simultaneously.

Power for the instrument is derived from a normal series stabilizer giving an output of 15 V. When operated on a.c. mains the output from a transformer is rectified and applied to the stabilizer, the regulation of which is such that no intermediate taps are required in the transformer primary windings for the two ranges of input voltage. Similarly, it allows a wide range of battery voltage to be used for d.c. operation.

A neat mechanical layout results from the use of ten printed circuit boards for the main circuit sections. The boards are mounted on a common chassis, five above, five below, with electrostatic screens fitted between boards where necessary. Mounted on pivots to allow limited movement for servicing accessibility, the boards are retained by easily removable screws in channels riveted to each board. Although the boards have printed plug interconnections these are only used for initial testing purposes; when they are finally assembled into the instrument soldered connections are used to avoid contact troubles.

The iron dust tuning core of the local oscillator is actuated by a precision lead screw of 10 turns per inch. The required frequency range of 100 to 150 kc/s is given by a movement of 0.85 in, i.e, 8.5 turns of the tuning control. The frequency scale is an 8.5 turn spiral, the appropriate part of the scale in use being indicated by a coloured marker behind the dial. 'Add up' type stops on the control mehcanism limit the lead screw travel.

In order to facilitate the determination of meter scale multiplying factor a simple mechanical computer is used to combine the functions of the two attenuators. A dial mounted on the VOLTMETER RANGE switch spindle but driven by the MAX INPUT switch is printed with the fifteen range full scale values. The dial is viewed through a window on the front panel such that only seven ranges are visible at any one time, this being the coverage of the METER RANGE switch; the selected range f.s.d. is indicated by the switch knob pointer.

3.2 CIRCUIT SUMMARY

The basic arrangement of the main circuit sections on ten printed boards also provides a convenient breakdown for the following circuit description. That section of the main circuit on any one board is shown enclosed by a broken line on the circuit diagram and each board is identified by a 'TM' number.

Input Amplifier, TM 6957

The 30 mV output from the compensated input attenuator is fed to this amplifier which is a three stage feedback type having a loop voltage gain of 6. The first common emitter stage, VT50, uses a silicon p-n-p transistor for high gain with low noise and distortion. The next stage, VT51, has its base bias variable by RV51 which is set for minimum distortion. The output from this stage is fed to emitter follower VT52, with overall feedback to the emitter of VT50. Diodes MR50 and MR51 are included to protect VT50 from damage due to excessive input voltage.

For absolute measurements the overall gain is fixed, but for relative measurements a variable

resistor, RV1, (the SET REFERENCE control), is switched into the emitter circuit of VT50 to give up to 10 dB of gain reduction for level setting purposes.

Low-Pass Filter and Ring Bridge Modulator, TM 6875

The low pass filter is an m-derived network having an iterative impedance of 1000 Ω. The frequency response is flat to within 0.16 dB up to 50 kc/s, with attenuation at 100 kc/s greater than 44 dB.

The conventional ring bridge modulator consists of MR70 to MR73, with a 1000 Ω resistor in series with each diode to swamp differences in forward resistance. The diodes are mounted on a covered B9A plug, TM 7252, thus enabling easy replacement if required, and providing a convenient point for applying a test signal for servicing purposes. Two preset potentiometers, RV2 and RV3, are mounted remote from the board on the front panel, these being the BALANCE controls which are adjusted for maximum carrier suppression.

The secondary winding of the ring bridge output transformer, T71, is tuned to 100 kc/s and the output fed to the first crystal filter on TM 7094 via an emitter follower stage, VT70.

Two Crystal Filter, TM 7094

This crystal filter comprises two quartz resonators operating in the series mode and coupled by shunt capacity. Variable resistors and capacitors connected in series with the crystals permit adjustment of Q and resonant frequency to give an overcoupled band pass characteristic. A portion of the input signal is fed past this filter section and is added to the output in such a phase as to produce nulls in the output at about 45 c/s either side of the centre frequency. This gives a double-humped response with sharp cut-off.

The filter output is fed via a common emitter stage, VT140, to the i.f. attenuator.

Single Crystal Filter and I.F. Amplifier, TM 7095

The output of the i.f. attenuator is fed to a tuned amplifier, VT160, then to a second crystal filter. This is a single quartz resonator operated in the series mode at 100 kc/s. Series capacitor C165 and variable resistor RV160 are included for adjustment of resonant frequency and Q respectively. The result is a bandwidth of 7 c/s with very sharp cut-off beyond it.

The filter output is applied to a two stage feedback amplifier, VT161 and VT162, having a high input impedance and a voltage gain of approximately 150. This is followed by a further amplifier stage, VT163, which has variable gain. The SET CALIBRATION control, RV4, in the emitter circuit is used for adjusting the gain when calibrating the voltmeter.

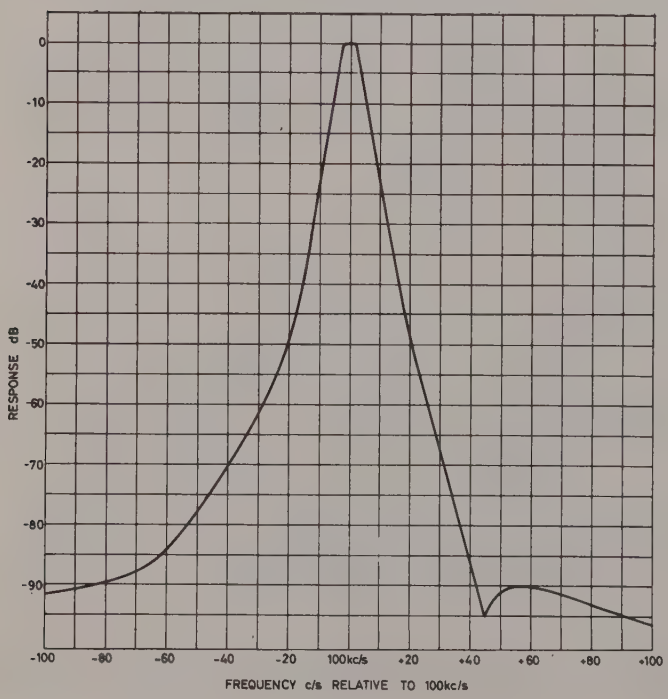


Fig. 3.2

Typical response of the crystal filters

Meter Amplifier and Rectifier, TM 7096

The meter amplifier has two stages with the meter rectifier circuit connected in the negative feedback path between the emitter of VT191 and the base of VT190. The open loop gain of the amplifier is increased by controlled positive feedback from the emitter of VT191 to the emitter of VT190. This helps to linearize the meter scale shape. Two r.f. chokes are connected in series with the meter to prevent any 100 kc/s component from reaching the meter. An output, taken from the collector of VT191, is amplitude limited by diodes MR190 and MR191 and fed to the discriminator as drive for the a.f.c. circuit.

Crystal Discriminator, TM 7119

The 100 kc/s input signal from the meter amplifier is amplified by VT90 and fed to the crystal discriminator. This consists of two series networks, one with a quartz resonator, the other only resistors and capacitors. The voltages across the two arms are rectified and their difference is filtered before being fed as the a.f.c. signal to the local oscillator tuned circuit.

A second output, set by RV90, is routed via the FUNCTION switch to replace the a.f.c. signal in positions other than A. F. C. The discriminator characteristic is obtained by using both the resonant and anti-resonant frequencies of the crystal; the lower frequency peak is due to the series resonance and the upper frequency null is due to the parallel resonance (anti-resonance). The series resonant frequency is adjusted by C98 and the bandwidth by C99. C97 is made adjustable in order to equalize the outputs of the two detector circuits at the centre frequency.

100 kc/s Crystal Oscillator, TM 7121

This is basically two circuits: the crystal oscillator and the amplitude control circuit. The crystal, mounted remote from the board, is also used in the a.f.c. discriminator circuit.

The crystal is used in the series resonant mode in the oscillator connected between the collector of VT210 and the base of VT211, where VT210 is in a common base configuration and VT211 is an emitter follower. Capacitor C211 is used for precise adjustment of the oscillator frequency. Positive feedback is taken from the output to the emitter of VT210 via a forward biased diode MR210, the effective resistance of which is controlled by the amplitude control circuit.

The amplitude control circuit consists of a peak detector MR213 followed by a long tailed pair, VT212 and VT213, which compares the peak amplitudes with a standard direct voltage derived from a Zener diode, MR211. In order to back off the temperature effects of the detector diode a similar diode, MR212, is connected in series with the reference voltage.

Local Oscillator, TM 6965

The oscillator circuit comprises common emitter amplifier VT110 and an emitter follower VT111. Feedback is taken via a forward biased diode MR112 and transformer T110, the amplitude of the feedback being controlled by the d.c. flowing through the diode. The tuned circuit of the oscillator is in the collector circuit of VT110, padder and trimmer inductors L112 and L113 being included to enable the frequency law to be adjusted to fit a pre-calibrated scale. Zener diode MR111 holds the collector/base voltage of VT110 constant in order to minimize frequency drift with temperature.

The voltage variable capacitor MR110 is biased by the output of the a.f.c. discriminator to lock the oscillator frequency to the input signal under test. For positions of the FUNCTION switch other than A. F. C. the discriminator provides a fixed bias for MR110.

The output from VT111 is fed to a feedback amplifier having a class B push-pull output stage using n-p-n/p-n-p transistors VT114 and VT115. The gain of this amplifier is approximately 15. A portion of the output is rectified by MR114 and compared with the voltage at the junction of R130 and R131. The resultant error voltage is used to control the current through MR112 for amplitude control as described above.

Modulator, Low-Pass Filter and Output Amplifier, TM 7123

The b.f.o. output is obtained by mixing the output of the local oscillator with that of the 100 kc/s crystal oscillator in another transformer fed ring bridge. Since carrier suppression is not critical in this case no balance adjustments are included. The difference frequency is then filtered by an m-derived filter similar to that used in the voltmeter input circuit.

The output amplifier consists of three common emitter stages in cascade with overall feedback from the emitter of VT242 to the emitter of VT240. In order to facilitate direct coupling of the stages an n-p-n transistor is used for the third stage, VT242.

The output, taken from potentiometer RV5 (the OUTPUT LEVEL control) in the collector circuit of VT242, is variable up to 1 V r.m.s.; a second output, from the emitter, provides the drive for the amplitude control circuit on TM 7121.

Power Supply, TM 7116

This board consists of two sections, the rectifier and filter for the a.c. from the mains transformer and the voltage stabilizer circuit. The former is a conventional full wave rectifier using silicon diodes, MR260 and MR261. The rectified output is smoothed by a capacitor input filter comprising C260, R260 and C261.

The stabilizer input is derived either from the rectifier when operating from a.c. mains or direct from an external battery with d.c. operation. An amplifier, VT260, compares a portion of the output voltage from the series stabilizer, VT1 (mounted remote from the board), with a reference voltage derived from a Zener diode, MR262. The resultant error signal is fed via an emitter follower, VT261, to the base of the series transistor. The decoupling circuit R261 and C265 ensures that the collector supply to VT260 is free from ripple. Potentiometer RV260 is used to set up the output voltage, i.e., -15 V.

Protection for the instrument is provided by MR1, FS1 and FS2, all remote from the board. Diode MR1 prevents damage occurring due to an external d.c. supply being connected with reversed polarity. Fuse FS1 protects the a.c. mains input and FS2 protects VT1 in the event of the stabilizer output being short circuited.

Chapter 4

Maintenance

The full specification performance of this instrument is obtained only after a precise setting up procedure involving special test equipment has been carried out at the factory. The information given in this chapter, therefore, is intended for simple fault finding and routine adjustment purposes only. Any maintenance outside the scope of this information will necessitate returning the instrument to our Service Department; for the address see the rear cover of this manual.

Before attempting any maintenance on the analyser you are advised to read the preceding Technical Description chapter.

4.1 REMOVAL OF CASE

The case assembly is retained by four 2BA Phillips round head screws, one at each corner of the rear panel. Turn the instrument on its front, remove the four screws and the mains lead and lift off the case assembly.

The analyser may be adapted for mounting in a standard 19 inch rack. A conversion kit for this purpose, TM 8271, is available from our Service Department; (fitting instructions are supplied with it).

4.2 ACCESS TO PRINTED CIRCUIT BOARDS

The printed boards are mounted in pivot blocks and are clamped to the chassis by long screws in channels at the edges of each board. The electrostatic screening plates that are mounted between some boards are held in plastic clips and clamped in the same way as the boards. In order to make a printed board more accessible for measurement purposes remove the clamping screws from the board and any adjacent screens and pull out the screens; the board may then be tilted over to reveal the printing wiring.

4.3 A.C. MAINS INPUT RANGES

The mains input transformer for a. c. operation has two primary windings which are connected in parallel for the 115 V range or in series for the 230 V range. The transformer is mounted in a screening can on the underside of the chassis beneath the main tuning assembly. The primary connections of the transformer are brought out via feed-through terminals; these may be reached more easily if the chassis side plate is removed and the adjacent printed board tilted outwards. The plate is retained by two 4BA screws near its upper edge; see Section 4.2 regarding the printed board.

The terminal interconnections are printed on the side of the transformer can and are repeated in Fig. 4.1.

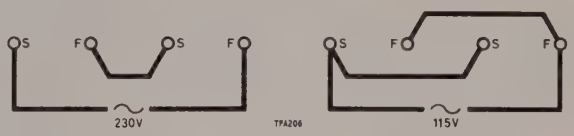


Fig. 4.1 Mains input connections

4.4 FAULT FINDING

The following functional check and the transistor static voltages given in Table 4.1 should enable any circuit malfunction to be easily traced. The functional check entails connecting the B. F. O. output to the voltmeter INPUT terminals; with the meter slider switch set to VOLTMETER, the MAX INPUT and VOLTMETER RANGE switches set to 1 V and an output frequency of 5 kc/s, adjust the OUTPUT LEVEL control to give f. s. d. on the meter. The typical stage output voltages and waveforms should then be similar to those given in Fig. 4.2.

When it is obvious that the simple replacement of a faulty component will restore normal working conditions such a replacement is permissible. However, when the replacement is liable to affect an important circuit function, such as the frequency calibration of an oscillator or the response of a filter, it should not be undertaken since any subsequent readjustment of associated preset components necessitated by the replacement should only be carried out by the manufacturer.

When replacing a semiconductor remember that lead out wires should not be bent close to the seal and, when soldering a connection, the use of thermal shunt is recommended.

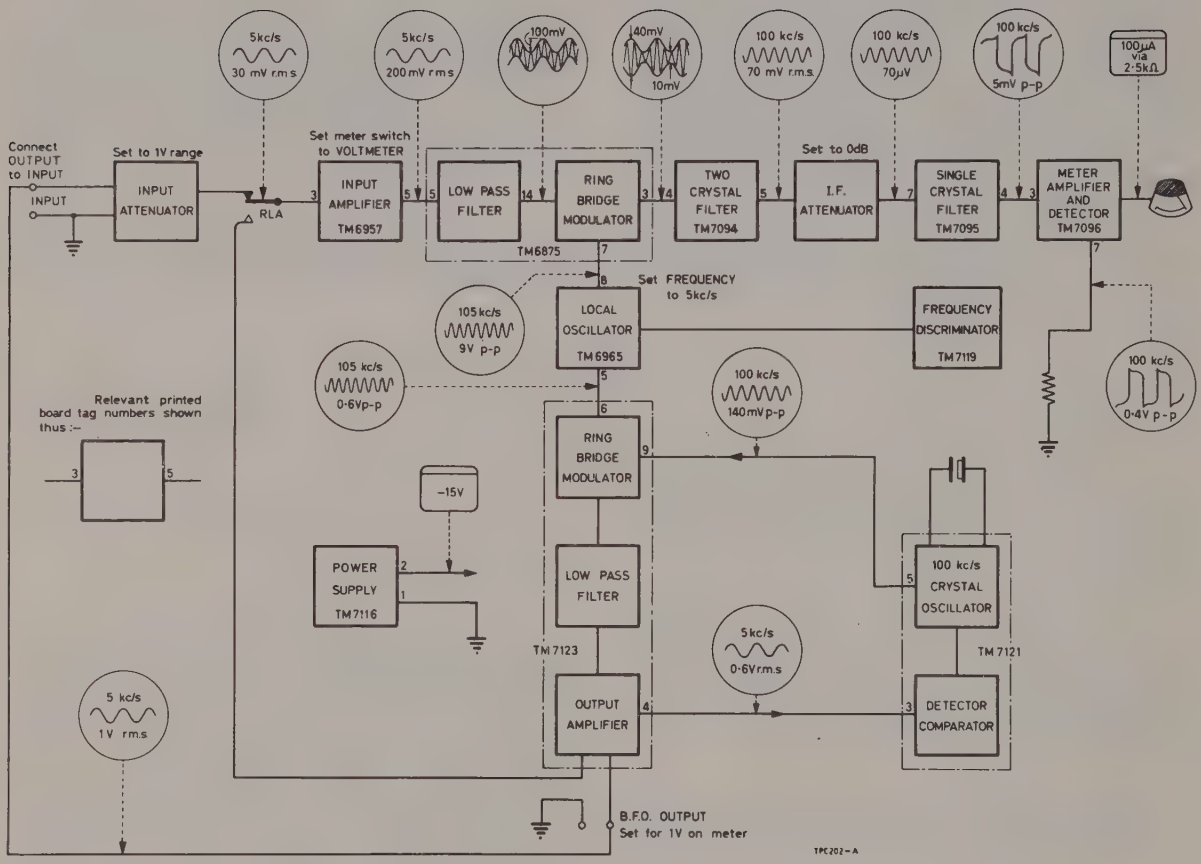


Fig. 4.2 Functional check

TABLE 4.1

Board no.	Circuit ref. no.	Emitter	Collector
TM 6957	VT50	-5.5 V	-13.5 V
	VT51	-6 V	-8 V
	VT52	-8 V	-14.5 V
TM 6875	VT70	-7.2 V	-14.9 V
TM 7094	VT140	-4.5 V	-14.9 V
TM 7095	VT160	-4.1 V	-14.9 V
	VT161	-2.8 V	-7.2 V
	VT162	-7.2 V	-10.3 V
	VT163	-3.2 V	-10 V
TM 7096	VT190	-1.5 V	-6.9 V
	VT191	-6.7 V	-12.2 V
TM 7119	VT90	-2.5 V	-13.5 V
TM 7121	VT210	-12 V	-4 V
	VT211	-6.5 V	-13 V
	VT212	-5 V	-9.6 V
	VT213	-5 V	-13 V
TM 6965	VT110	-7.8 V	-14.6 V
	VT111	-3.2 V	-14.7 V
	VT112	-0.66 V	-7.8 V
	VT113	-7.5 V	-14.5 V
	VT114	-7.2 V	0
	VT115	-7.4 V	-14.5 V
TM 7123	VT240	-3.4 V	-7.4 V
	VT241	-7.3 V	-10.6 V
	VT242	-10.8 V	-6.6 V *
TM 7116	VT260	-8.9 to -10.9 V	-15.4 V
	VT261	-15.2 V	-25 V
	VT1	-15 V	-25 V

Static voltages measured relative to chassis.

* RV6 at maximum.

Chapter 5

Replaceable parts

Introduction

This section lists replaceable parts in alphabetical order of their circuit references, with miscellaneous parts at the end of the list. The following abbreviations and symbols are used:-

C	:	capacitor
Carb	:	carbon
Cer	:	ceramic
CRT	:	cathode ray tube
Elec	:	electrolytic
FS	:	fuse
JK	:	jack
L	:	inductor
Log	:	logarithmic law
M	:	meter
Met	:	metal
Min	:	minimum value
MR	:	semiconductor diode
Ox	:	oxide
PL	:	plug
Plas	:	plastic
R	:	resistor
RV	:	variable resistor
S	:	switch
SKT	:	socket
T	:	transformer
TE	:	total excursion
TH	:	thermistor
TP	:	terminal
V	:	valve
Var	:	variable
VT	:	transistor
WW	:	wirewound
XL	:	crystal
†	:	value selected during test; nominal value listed.
ϕ	:	feed-through component
W	:	watts at 70°C
W*	:	watts at 55°C
W**	:	watts at 40°C
W***	:	watts at 20°C
W°	:	watts at unspecified temperature

Ordering

Send your order for replacement parts to our Service Division at the address given on the back cover. Specify the following information for each part required:

1) Type and serial number of instrument
2) Circuit reference
3) Description
4) M.I. code number

If a part is not listed, state its function, location and description when ordering.

Circuit reference	*Description*	*M.I. code*
C1	Cer 100pF ±2% 750 V	26224-897
C2	Cer 8 - 50pF Var	26845-108
C3	Cer 8 - 50pF Var	26845-108
C6	Elec 100μF +100% -20% 25 V	26417-158
C7	Air 6 - 98.4pF Var	26812-173
C9	Elec 500μF +50% -20% 15 V	26417-173
C10	Plas 0.001μF ±20% 500 V	26174-125
C50	Elec 250μF +100% -20% 25 V	26417-167
C51	Plas 1μF ±10% 400 V	26512-284
C52	Elec 25μF +100% -20% 25 V	26417-143
C53	Elec 1000μF +50% -20% 12 V	26417-403
C54	Elec 100μF +100% -20% 6 V	26417-154
C55	Elec 100μF +100% -20% 6 V	26417-154
C56	Mica 1800pF ±5% 200 V	26268-366
C57	Elec 100μF ±20% 10 V	26486-606
C70	Mica 2034pF ±1% 200 V	26268-368
C71	Mica 306pF ±1% 350 V	26268-353
C72	Mica 4145pF ±1% 200 V	26268-386
C73	Mica 906pF ±1% 350 V	26268-358
C74	Mica 1570pF ±1% 200 V	26268-364
C75	Mica 4700pF ±1% 200 V	26268-389
C76	Elec 0.01μF ±20% 400 V	26417-147
C77	Elec 5μF +50% -20% 70 V	26417-118
C90	Elec 5μF +100% -20% 70 V	26417-152
C91	Mica 0.001μF ±1% 350 V	26268-360
C92	Plas 0.1μF ±25% 350 V	26174-173

Circuit reference	Description	M.I. code
C93	Plas 0.1μF ±25% 350 V	26174-173
C94	Mica 68pF ±1% 350 V	26268-317
C95	Mica 100pF ±1% 350 V	26268-324
C96	Plas 0.25μF ±10% 50 V	26174-175
C97	Cer 3 - 40pF Var	26848-215
C98	Cer 3 - 40pF Var	26848-215
C99	Cer 10 - 40 pF Var	26847-265
C100	Plas 0.1μF ±25% 350 V	26174-173
C101	Elec 330μF ±20% 6 V	26486-630
C102	Elec 330μF ±20% 6 V	26486-630
C110	Elec 100μF ±20% 10 V	26486-606
C111	Plas 0.1μF ±20% 200 V	26582-208
C112	Mica 9610pF ±0.5% 200 V	26257-386
C113	Cer 390pF ±10% 500 V	26361-924
C114	Elec 100μF ±20% 10 V	26486-606
C115	Elec 25μF +100% -20% 25 V	26417-143
C116	Plas 0.1μF ±20% 200 V	26582-208
C117	Plas 0.1μF ±20% 200 V	26582-208
C118	Plas 0.1μF ±20% 200 V	26582-208
C119	Plas 0.01μF ±20% 200 V	26582-232
C120	Elec 100μF ±20% 10 V	26486-606
C121	Plas 0.01μF ±20% 200 V	26582-232
C122	Plas 0.1μF ±20% 200 V	26582-208
C123	Plas 0.01μF ±20% 200 V	26582-232
C124	Plas 0.25μF ±10% 150 V	26174-175
C140	Plas 0.01μF ±20% 400 V	26174-147
C141	Mica 33pF ±5% 350 V	26268-308
C142	Air 3 - 34pF Var	26812-314
C143	Mica 800pF ±5% 350 V	26268-356
C144	Plas 0.1μF ±25% 350 V	26174-173
C145	Mica 33pF ±5% 350 V	26268-308
C146	Air 3 - 34pF Var	26812-314
C147	Mica 0.001μF ±1% 350 V	26268-360
C148	Plas 0.1μF ±25% 350 V	26174-173
C149	Elec 5μF +50% -20% 70 V	26417-118
C150	Air 3 - 12.15pF Var	26812-311
C151	Air 3 - 12.15pF Var	26812-311
C160	Plas 0.04μF ±20% 200 V	26174-161
C161	Mica 0.001μF ±1% 350 V	26268-360
C162	Plas 0.1μF ±25% 350 V	26174-173
C163	Plas 0.1μF ±25% 350 V	26174-173
C164	Mica 33pF ±5% 350 V	26268-308
C165	Air 3 - 34pF Var	26812-314
C166	Plas 0.1μF ±25% 350 V	26174-173
C167	Plas 0.25μF ±10% 150 V	26174-175
C168	Plas 0.25μF ±10% 150 V	26174-175
C169	Elec 5μF +100% -20% 15 V	26414-113
C170	Elec 5μF +50% -20% 70 V	26417-118
C171	Plas 0.04μF ±20% 200 V	26174-161
C172	Air 3 - 12.15pF Var	26812-311
C191	Elec 5μF +50% -20% 70 V	26417-118
C192	Elec 5μF +50% -20% 70 V	26417-118
C193	Elec 5μF +50% -20% 70 V	26417-118
C194	Plas 0.25μF ±10% 150 V	26174-175
C195	Plas 0.1μF ±25% 350 V	26174-173
C196	Plas 0.25μF ±10% 150 V	26174-175
C197	Plas 0.25μF ±10% 150 V	26174-175
C198	Plas 0.1μF ±25% 350 V	26174-173
C210	Plas 100μF +100% -20% 25 V	26417-158
C211	Cer 3 - 40pF Var	26848-215
C212	Mica 22pF ±5% 350 V	26268-303
C213	Plas 0.1μF ±25% 350 V	26174-173
C214	Plas 0.04μF ±20% 200 V	26174-161
C215	Plas 0.1μF ±25% 350 V	26174-173
C216	Elec 25μF +100% -20% 25 V	26417-143
C217	Elec 100μF +100% -20% 6 V	26417-154
C218	Elec 5μF +50% -20% 70 V	26417-118

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
C219	Elec 100μF +100% -20% 25 V	26417-158
C220	Plas 0.02μF ±20% 200 V	26174-151
C240	Mica 2034pF ±1% 200 V	26268-368
C241	Mica 306pF ±1% 350 V	26268-353
C242	Mica 4145pF ±1% 200 V	26268-386
C243	Mica 906pF ±1% 350 V	26268-358
C244	Mica 1570pF ±1% 200 V	26268-364
C245	Elec 100μF +100% -20% 6 V	26417-154
C246	Elec 100μF +100% -20% 6 V	26417-154
C247	Elec 100μF +100% -20% 25 V	26417-158
C248	Elec 500μF +100% -20% 15 V	26417-173
C260	Elec 500μF +50% -20% 50 V	26417-178
C261	Elec 500μF +50% -20% 50 V	26417-178
C262	Plas 0.04μF ±20% 200 V	26174-161
C263	Elec 50μF +100% -20% 12 V	26417-152
C264	Elec 250μF +100% -20% 25 V	26417-167
C265	Elec 25μF +100% -20% 70 V	26417-145
C266 †	Plas 100pF ±2% 125 V	26526-241

Circuit reference	Description	M.I. code
L1	Var inductor (FREQUENCY)	44161-402
L70	Inductor	44266-817
L71	Inductor	44266-818
L90	Inductor	44266-819
L91	Inductor	44263-203
L111	Inductor	44272-416
L112	Var inductor	44262-814
L113	Var inductor	44268-417
L114	Inductor	44272-416
L190	Inductor	44272-416
L191	Inductor	44272-416
L240	Inductor	44266-817
L241	Inductor	44266-818
M1	800Ω 100μA	44572-202

FS1	Quick blow 160mA	23411-003
FS2	Delay 50mA (230 V range)	23411-051
	100mA (115 V range)	23411-052
JK1	Socket, 2 pole	23421-685

MR1	1N540	28357-044
MR50	1S920	28336-138
MR51	1S920	28326-138
MR70	AAZ12	28331-618
MR71	AAZ12	28331-618
MR72	AAZ12	28331-618
MR73	AAZ12	28331-618
MR90	CG85-H	28321-201
MR91	CG85-H	28321-201
MR110	100SC2	28381-297
MR111	Z6.2 ±5%	28371-486
MR112	HG1005	28323-035
MR113	HG1005	28323-035
MR114	HG1005	28323-035

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
MR190	CG85-H	28321-201
MR191	CG85-H	28321-201
MR192	HG1005	28323-035
MR193	HG1005	28323-035
MR210	HG1005	28323-035
MR211	Z6.2 ±5%	28371-486
MR212	HG1005	28323-035
MR213	HG1005	28323-035
MR240	AAZ12	28331-618
MR241	AAZ12	28331-618
MR242	AAZ12	28331-618
MR243	AAZ12	28331-618
MR260	1N540	28357-044
MR261	1N540	28357-044
MR262	Z10 ±10%	28371-846
PL1	3 pin 3 A	23423-151
RLA	350Ω 12 V	23486-110
R1	Met ox 3300Ω ±1% ¼W	24637-201
R2	Met ox 7811Ω ±1% ¼W	24637-401
R3	Met ox 90kΩ ±1% 1W	24667-651
R4	Met ox 46.2kΩ ±1% ½W	24657-201
R5	Met ox 68.37kΩ ±1% 1W	24667-601
R6	Met ox 990kΩ ±1% ¼W	24637-851
R7	Met ox 7.840kΩ ±1% ¼W	24637-402
R8	Met ox 2.250kΩ ±1% ¼W	24637-104
R9	Met ox 693Ω ±1% ¼W	24636-801
R10	Met ox 217Ω ±1% ¼W	24636-604
R11	Met ox 100Ω ±1% ¼W	24636-601
R12	Carb 4.7kΩ ±10% ½W	24342-100
R15	Met ox 820Ω ±7% TE 3/8W*	24552-078
R16	Met ox 1297Ω ±½% ¼W	24635-003
R17	Met ox 877.5Ω ±½% ¼W	24634-802
R18	Met ox 1297Ω ±½% ¼W	24635-003
R19	Met ox 877.5Ω ±½% ¼W	24634-802
R20	Met ox 1297Ω ±½% ¼W	24635-003
R21	Met ox 877.5Ω ±½% ¼W	24634-802
R22	Met ox 1297Ω ±½% ¼W	24635-003
R23	Met ox 877.5Ω ±½% ¼W	24634-802
R24	Met ox 1297Ω ±½% ¼W	24635-003
R25	Met ox 877.5Ω ±½% ¼W	24634-802
R26	Met ox 1297Ω ±½% ¼W	24635-003
R27	Met ox 600Ω ±½% ¼W	24634-801
R28	Carb 10kΩ ±10% ½W*	24342-110
R50	Carb 100Ω ±10% ½W*	24342-050
R51	Met ox 10kΩ ±7% TE 3/8W*	24552-110
R52	Met ox 8.2kΩ ±7% TE 3/8W*	24552-108
R53	Met ox 96kΩ ±1% ¼W	24637-651
R54	WW 3.3kΩ ±5% 8W***	25125-652
R55	Carb 22kΩ ±10% ½W*	24342-118
R56	Met ox 510Ω ±7% TE 3/8W*	24552-071
R57	Carb 4.7kΩ ±10% ½W*	24342-100
R58	Met ox 2.7kΩ ±7% TE 3/8W*	24552-092
R59	Met ox 3.9kΩ ±7% TE 3/8W*	24552-096
R60	Met ox 22kΩ ±7% TE 3/8W*	24552-118
R61	Met ox 1.2kΩ ±7% TE 3/8W*	24552-082
R62	Met ox 3.3kΩ ±7% TE 3/8W*	24552-094

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
R63	Carb 2.7kΩ ±10% ½W*	24342-092
R70	Met ox 1kΩ ±1% ¼W	24637-101
R71	Met ox 510Ω ±7% TE 3/8W*	24552-071
R72	Met ox 750Ω ±7% TE 3/8W*	24552-077
R73	Met ox 430Ω ±7% TE 3/8W*	24552-067
R74	† Met ox 820Ω ±7% TE 3/8W*	24552-078
R75	† Met ox 820Ω ±7% TE 3/8W*	24552-078
R76	Met ox 1kΩ ±1% ½W	24657-101
R77	Met ox 1kΩ ±1% ½W	24657-101
R78	Met ox 1kΩ ±1% ½W	24657-101
R79	Met ox 1kΩ ±1% ½W	24657-101
R80	Met ox 1kΩ ±1% ½W	24657-101
R81	Met ox 1kΩ ±1% ½W	24657-101
R82	Carb 33kΩ ±10% ½W*	24342-122
R83	Carb 33kΩ ±10% ½W*	24342-122
R84	Carb 6.8kΩ ±10% ½W*	24342-106
R85	Carb 100Ω ±10% ½W*	24342-050
R90	Carb 100Ω ±10% ½W*	24342-050
R91	Carb 6.8kΩ ±10% ½W*	24342-106
R92	Carb 22kΩ ±10% ½W*	24342-118
R93	Carb 1.5kΩ ±10% ½W*	24342-084
R94	Met ox 100Ω ±7% TE 3/8W*	24552-050
R95	Carb 2.2kΩ ±10% ½W*	24342-088
R96	Met ox 6.8kΩ ±7% TE 3/8W*	24552-106
R97	Met ox 330Ω ±7% TE 3/8W*	24552-063
R98	Carb 100kΩ ±10% ½W*	24342-135
R99	Carb 100kΩ ±10% ½W*	24342-135
R100	Met ox 220Ω ±7% TE 3/8W*	24552-058
R101	Carb 2.2MΩ ±10% ½W*	24342-174
R110	Carb 6.8kΩ ±10% ½W*	24342-106
R111	Carb 3.9kΩ ±10% ½W*	24342-096
R112	Carb 68Ω ±10% ½W*	24342-043
R113	Carb 47kΩ ±10% ½W*	24342-126
R114	Carb 15kΩ ±10% ½W*	24342-114
R115	Carb 470Ω ±10% ½W*	24342-069
R116	Carb 820Ω ±10% ½W*	24342-078
R117	Carb 820Ω ±10% ½W*	24342-078
R118	Carb 4.7kΩ ±10% ½W*	24342-100
R119	Met ox 2.2kΩ ±7% TE 3/8W*	24552-088
R120	Met ox 33kΩ ±7% TE 3/8W*	24552-122
R121	Met ox 9.1kΩ ±7% TE 3/8W*	24552-109
R122	Carb 2.2kΩ ±10% ½W*	24342-088
R123	Carb 3.3kΩ ±10% ½W*	24342-094
R124	Met ox 560Ω ±7% TE 3/8W*	24552-072
R125	Carb 4.7kΩ ±10% ½W*	24342-100
R126	Carb 10Ω ±10% ½W*	24342-020
R127	Carb 10Ω ±10% ½W*	24342-020
R128	Met ox 150Ω ±7% TE 3/8W*	24552-054
R129	Met ox 1kΩ ±7% TE 3/8W*	24552-080
R130	Met ox 2.2kΩ ±7% TE 3/8W*	24552-088
R131	Carb 330Ω ±10% ½W*	24342-063
R132	Met ox 10kΩ ±7% TE 3/8W*	24552-110
R133	Carb 39kΩ ±10% ½W*	24342-124
R134	Carb 100Ω ±10% ½W*	24342-050
R140	Met ox 300Ω ±7% TE 3/8W*	24552-062
R141	Carb 27kΩ ±10% ½W*	24342-120
R142	Carb 15kΩ ±10% ½W*	24342-114
R143	Met ox 300Ω ±7% TE 3/8W*	24552-062
R144	Carb 33kΩ ±10% ½W*	24342-122
R145	Carb 4.7kΩ ±10% ½W*	24342-100
R146	Met ox 180Ω ±7% TE 3/8W*	24552-056
R147	Carb 100Ω ±10% ½W*	24342-050

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
R160	Carb 15kΩ ±10% ½W*	24342-114
R161	Carb 33kΩ ±10% ½W*	24342-122
R162	Carb 4.7kΩ ±10% ½W*	24342-100
R163	Met ox 180Ω ±7% TE 3/8W*	24552-056
R164	Carb 100Ω ±10% ½W*	24342-050
R165	Met ox 820Ω ±7% TE 3/8W*	24552-078
R166	Carb 6.8kΩ ±10% ½W*	24342-106
R167	Met ox 1kΩ ±7% TE 3/8W*	24552-080
R168	Carb 33kΩ ±10% ½W*	24342-122
R169	Carb 2.2kΩ ±10% ½W*	24342-088
R170	Met ox 180Ω ±7% TE 3/8W*	24552-056
R171	Carb 8.2kΩ ±10% ½W*	24342-108
R172	Met ox 27kΩ ±7% TE 3/8W*	24552-120
R173	Carb 6.8kΩ ±10% ½W*	24342-106
R174	Carb 3.3kΩ ±10% ½W*	24342-094
R175	Carb 10kΩ ±10% ½W*	24342-110
R176	Carb 33kΩ ±10% ½W*	24342-122
R177	Carb 2.2kΩ ±10% ½W*	24342-088
R178	Carb 100Ω ±10% ½W*	24342-050
R179	Carb 4.7kΩ ±10% ½W*	24342-100
R240	Met ox 1kΩ ±7% TE 3/8W*	24552-080
R241	Met ox 1kΩ ±7% TE 3/8W*	24552-080
R242	Met ox 220Ω ±7% TE 3/8W*	24552-058
R243	Met ox 220Ω ±7% TE 3/8W*	24552-058
R244	Met ox 4.7kΩ ±7% TE 3/8W*	24552-100
R245	Met ox 12kΩ ±7% TE 3/8W*	24552-112
R246	Carb 100Ω ±10% ½W*	24342-050
R247	Met ox 3.3kΩ ±7% TE 3/8W*	24552-094
R248	Met ox 180Ω ±7% TE 3/8W*	24552-056
R190	Met ox 4.7kΩ ±7% TE 3/8W*	24552-056
R191	Met ox 33kΩ ±7% TE 3/8W*	24552-078
R192	Carb 100Ω ±10% ½W*	24342-114
R193	Met ox 5.6Ω ±7% TE 3/8W*	24552-080
R194	Carb 1.8kΩ ±10% ½W*	24342-122
R195	Carb 8.2kΩ ±10% ½W*	24342-100
R196	Carb 2.7kΩ ±10% ½W*	24342-050
R197	Met ox 270Ω ±7% TE 3/8W*	24552-120
R198	Carb 1.2kΩ ±10% ½W*	24342-106
R199	Carb 2.2kΩ ±10% ½W*	24342-088
R200	Carb 100kΩ ±10% ½W*	24342-108
R210	Carb 470Ω ±10% ½W*	24342-069
R211	Carb 27kΩ ±10% ½W*	24342-120
R212	Carb 2.2kΩ ±10% ½W*	24342-088
R213	Carb 5.6kΩ ±10% ½W*	24342-103
R214	Carb 820Ω ±10% ½W*	24342-078
R215	Carb 22kΩ ±10% ½W*	24342-118
R216	Carb 22kΩ ±10% ½W*	24342-118
R217	Carb 6.8kΩ ±10% ½W*	24342-106
R218	Carb 1kΩ ±10% ½W*	24342-080
R219	Carb 10kΩ ±10% ½W*	24342-110
R220	Carb 3.3kΩ ±10% ½W*	24342-094
R221	Met ox 3.9kΩ ±7% TE 3/8W*	24552-096
R222	Met ox 680Ω ±7% TE 3/8W*	24552-076
R223	Carb 22kΩ ±10% ½W*	24342-118
R224	Carb 18kΩ ±10% ½W*	24342-116
R226	Carb 22kΩ ±10% ½W*	24342-118
R227	Carb 1kΩ ±10% ½W*	24342-080
R228	Met ox 10kΩ ±7% TE 3/8W*	24552-110
R252	Met ox 22kΩ ±7% TE 3/8W*	24552-118
R253	Met ox 330kΩ ±7% TE 3/8W*	24552-063
R254	Met ox 1.5kΩ ±7% TE 3/8W*	24552-084
R260	WW 47Ω ±5% 6W***	25125-337
R261	Carb 10kΩ ±10% ½W*	24342-110
R262	Carb 10kΩ ±10% ½W*	24342-110
R263	Carb 3.9kΩ ±10% ½W*	24342-096
R264	Met ox 3.9kΩ ±7% TE 3/8W*	24552-096
R265	Met ox 1.8kΩ ±7% TE 3/8W*	24552-086
R266	Carb 4.7kΩ ±10% ½W*	24342-100

For symbols and abbreviations see introduction to this chapter

Circuit reference	Description	M.I. code
RV1	WW 2.5kΩ ±10% 1W O	25853-127
RV2	WW 500Ω ±10% 3 W O	25823-408
RV3	WW 500Ω ±10% 3 W O	25823-408
RV4	WW 1kΩ ±10% 1 W O	25815-315
RV5	WW 600Ω ±10% 1 W O	25814-310
RV6	Carb 10kΩ ±20% ¼ W O	25611-126
RV50	Carb 15kΩ ±20% ¼ W O	25611-128
RV51	Carb 4.7kΩ ±20% ¼ W O	25611-122
RV90	WW 1kΩ ±10% 1 W O	25811-538
RV140	WW 1kΩ ±10% 1 W O	25811-538
RV141	WW 1kΩ ±10% 1 W O	25811-538
RV160	WW 1kΩ ±10% 1 W O	25811-538
RV190	Carb 470Ω ±20% ¼ W O	25611-110
RV191	Carb 1kΩ ±20% ¼ W O	25611-114
RV210	WW 1kΩ ±10% 1 W O	25811-538
RV260	Carb 1kΩ ±20% ¼ W O	25611-114
SA	MAX INPUT	44325-802
SB	VOLTMETER/RELATIVE	23467-115
SC	VOLTMETER RANGE	44325-107
SD	FUNCTION	44323-704
SE	SUPPLY	44321-406
SF	BATTERY/MAINS	24367-119
T1	Mains	43453-006
T70	Modulator	44266-212
T71	Modulator	44264-009
T110	Coupling	44268-416
T140	I. F. 100 kc/s	44266-820
T160	I. F. 100 kc/s	44266-820
T240	Modulator	44267-402
T241	Modulator	44267-402

Circuit reference	Description	M.I. code
TP1	Test point	23421-086
VT1	OC25	28424-807
VT50	HT101	28432-735
VT51	HT101	28432-735
VT52	2N404	28423-508
VT70	2N404	28423-508
VT90	NKT677	28422-714
VT110	HT101	28432-735
VT111	HT101	28432-735
VT112	HT101	28432-735
VT113	2N404	28423-508
VT114	2N1304	28443-528
VT115	2N404	28423-508
VT140	NKT677	28422-714
VT160	NKT677	28422-714
VT161	2N404	28423-508
VT162	2N404	28423-508
VT163	2N404	28423-508
VT190	NKT677	28422-714
VT191	2N404	28423-508
VT210	2N1304	28443-528
VT211	2N404	28423-508
VT212	HT100	28432-725
VT213	HT100	28432-725
VT240	2N404	28423-508
VT241	2N404	28423-508
VT242	2N1304	28443-528
VT260	2N404	28423-508
VT261	ACY17	28426-497
XL90	QM120/F	28311-350
XL140	QM120/F	28311-350
XL141	QM120/F	28311-350
XL160	QM120/F	28311-350

For symbols and abbreviations see introduction to this chapter

Chapter 6

Circuit diagrams

Circuit notes

1. COMPONENT VALUES

Resistors: No suffix = ohms, k = kilohms, M = megohms.
Capacitors: No suffix = microfarads, p = picofarads.
† value selected during test, nominal value shown.

2. SYMBOLS

arrow indicates clockwise rotation of knob.
FUNCTION etc., external front or rear panel marking.
tag on printed board.
other tag.
preset control.
printed board designation.
test point.
main signal path.
control or modulation path.
point marked with this symbol is connected to a similarly marked point.

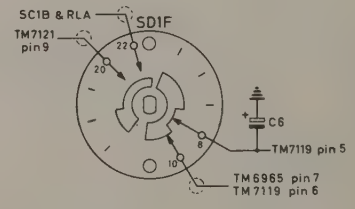
3. VOLTAGES

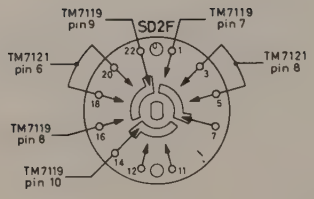
Shown in italics adjacent to point to which the measurement refers. DC relative to chassis unless otherwise stated.

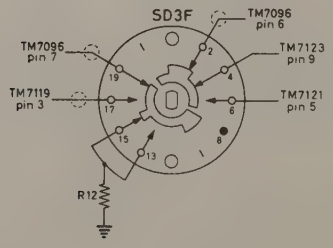
4. SWITCHES

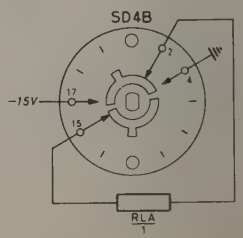
Rotary switches are drawn schematically.
The sections are identified
1st section, front: 1F
1st section, back: 1R
2nd section, front: 2F
2nd section, back: 2R
etc

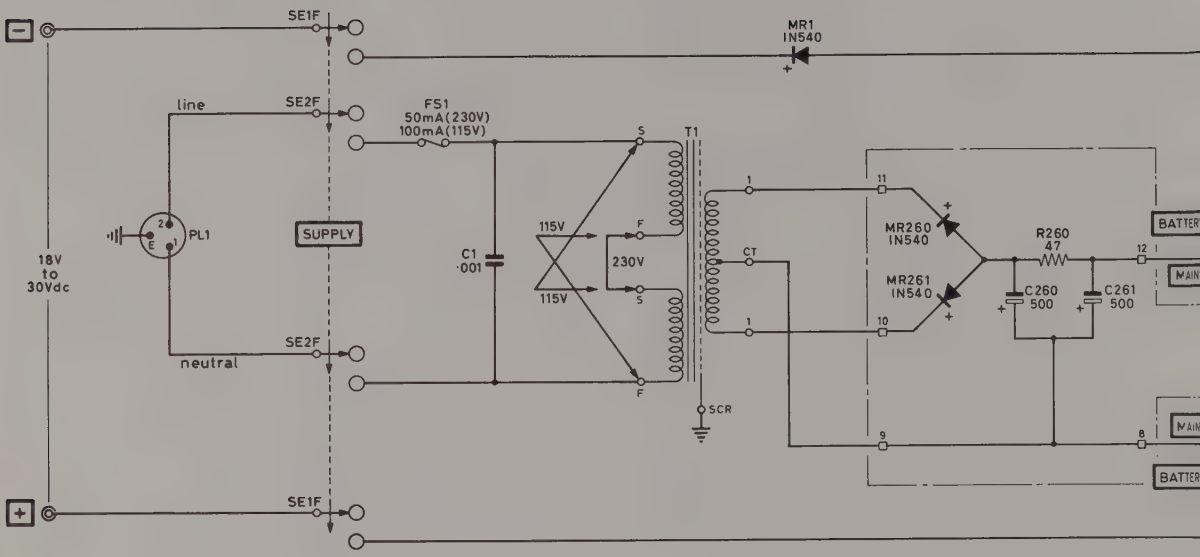
switch diagrams










SE1F
MR1
IN540
line
SE2F
FS1
50mA(230V)
100mA(115V)
S
T1
1
11
MR260
IN540
R260
47
12
BATTER
18V
to
30Vdc
2
E
1
PL1
SUPPLY
C1
·001
115V
F
230V
S
115V
CT
MR261
IN540
C260
500
C261
500
MAIN
1
10
neutral
SE2F
F
SCR
9
8
MAIN
BATTER
SE1F

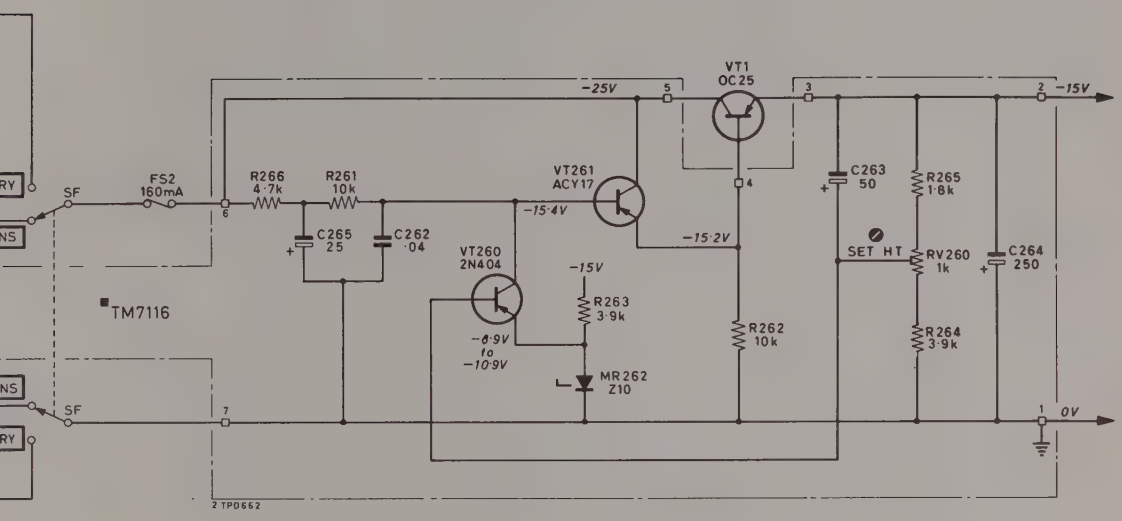
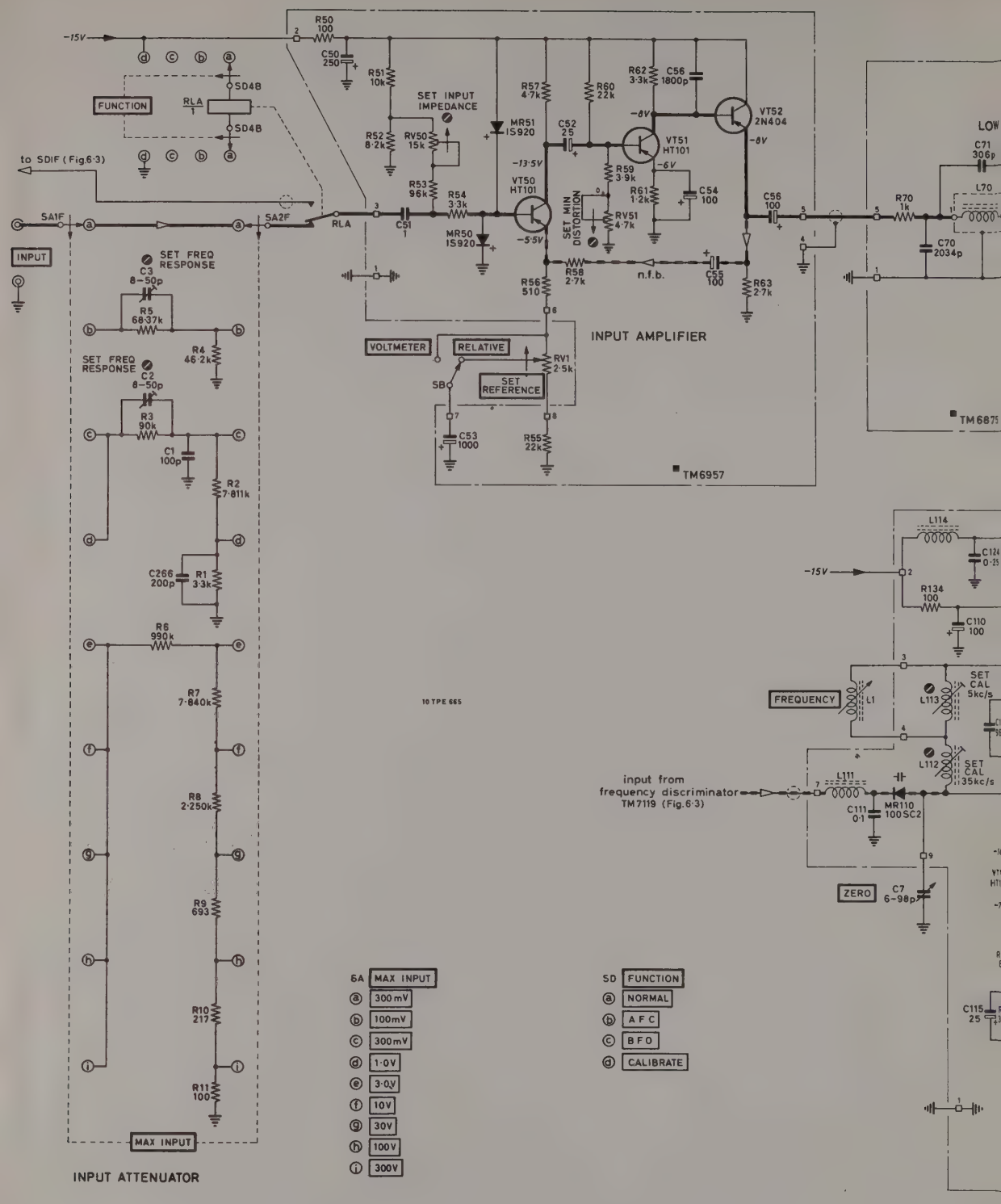


Fig. 6.1 Power supply


-15V
R50 100
C50 250
R51 10k
SET INPUT IMPEDANCE
R52 8·2k
RV50 15k
R53 96k
R54 3·3k
C51 1
MR50 IS920
MR51 IS920
R57 4·7k
R60 22k
R62 3·3k
C56 1800p
VT52 2N404
C52 25
VT51 HT101
R59 3·9k
R61 1·2k
C54 100
VT50 HT101
SET MIN DISTORTION
RV51 4·7k
C56 100
R70 1k
C71 306p
L70
C70 2034p
LOW
FUNCTION
RLA
SD4B
to SDIF (Fig.6·3)
SA1F
SA2F
INPUT
SET FREQ RESPONSE
C3 8–50p
R5 68·37k
R4 46·2k
C2 8–50p
R3 90k
C1 100p
R2 7·811k
C266 200p
R1 3·3k
R6 990k
R7 7·840k
R8 2·250k
R9 693
R10 217
R11 100
MAX INPUT
INPUT ATTENUATOR
R56 510
R58 2·7k
n.f.b.
C55 100
R63 2·7k
INPUT AMPLIFIER
VOLTMETER
RELATIVE
SB
SET REFERENCE
RV1 2·5k
C53 1000
R55 22k
TM6957
TM6875
L114
C124 0·25
R134 100
C110 100
FREQUENCY
L1
L113
SET CAL 5kc/s
L112
SET CAL 35kc/s
L111
input from frequency discriminator TM7119 (Fig.6·3)
C111 0·1
MR110 100SC2
ZERO
C7 6–98p
C115 25
10 TPE 665
5A MAX INPUT
ⓐ 300mV
ⓑ 100mV
ⓒ 300mV
ⓓ 1·0V
ⓔ 3·0V
ⓕ 10V
ⓖ 30V
ⓗ 100V
ⓘ 300V
5D FUNCTION
ⓐ NORMAL
ⓑ AFC
ⓒ BFO
ⓓ CALIBRATE

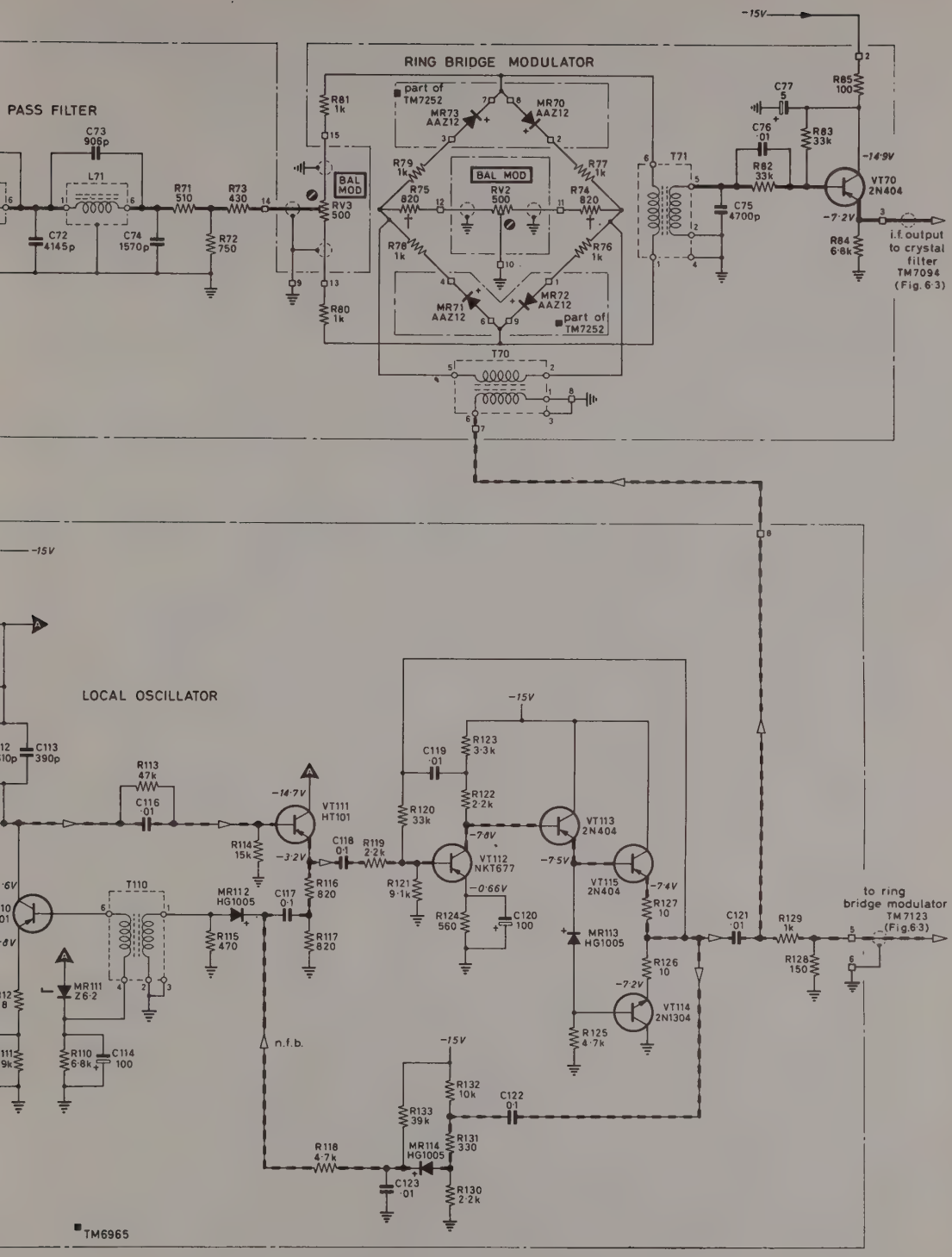
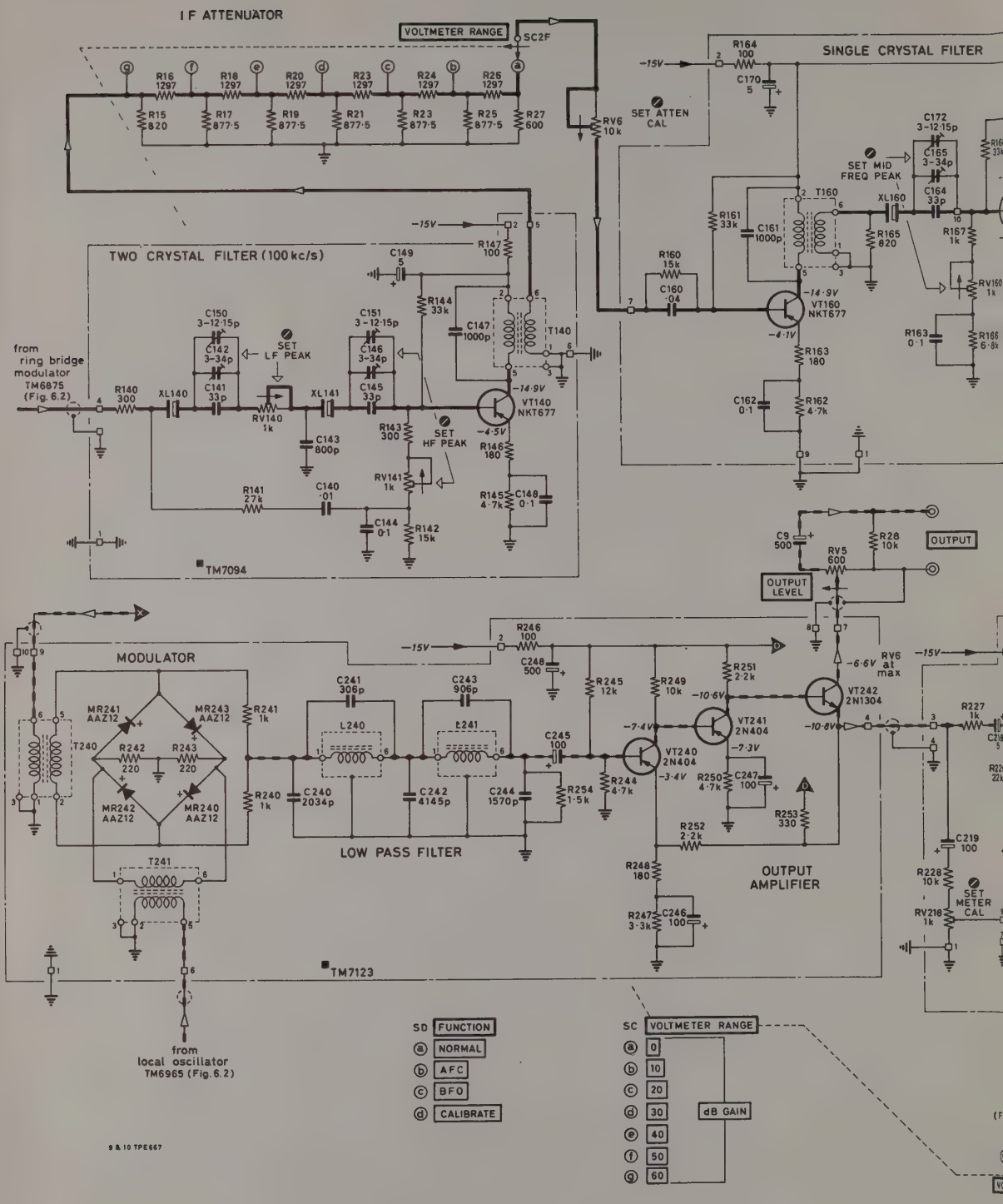


Fig. 6.2 Input stages


I F ATTENUATOR
VOLTMETER RANGE
SC2F
R16 1297
R18 1297
R20 1297
R23 1297
R24 1297
R26 1297
R15 820
R17 877·5
R19 877·5
R21 877·5
R23 877·5
R25 877·5
R27 600
RV6 10k
SET ATTEN CAL
SINGLE CRYSTAL FILTER
-15V
R164 100
C170 5
C172 3-12·15p
C165 3-34p
C164 33p
SET MID FREQ PEAK
T160
XL160
R161 33k
C161 1000p
R165 820
R160 15k
C160 ·04
VT160 NKT677
-14·9V
-4·1V
R163 180
C162 0·1
R162 4·7k
R167 1k
RV160 1k
R163 0·1
R166 6·8k
TWO CRYSTAL FILTER (100 kc/s)
C149 5
R147 100
R144 33k
C147 1000p
T140
C150 3-12·15p
C142 3-34p
C141 33p
SET LF PEAK
RV140 1k
C151 3-12·15p
C146 3-34p
C145 33p
XL140
XL141
R140 300
from ring bridge modulator TM6875 (Fig. 6.2)
VT140 NKT677
-14·9V
-4·5V
R143 300
SET HF PEAK
RV141 1k
R146 180
C143 800p
C140 ·01
R141 27k
C144 0·1
R142 15k
R145 4·7k
C148 0·1
TM7094
C9 500
R28 10k
OUTPUT
RV5 600
OUTPUT LEVEL
MODULATOR
MR241 AAZ12
MR243 AAZ12
MR242 AAZ12
MR240 AAZ12
T240
R242 220
R243 220
R241 1k
R240 1k
T241
R246 100
C248 500
C241 306p
C243 906p
L240
L241
C240 2034p
C242 4145p
C244 1570p
C245 100
R245 12k
R249 10k
R244 4·7k
R254 1·5k
LOW PASS FILTER
R251 2·2k
VT242 2N1304
VT241 2N404
VT240 2N404
-10·6V
-7·4V
-3·4V
-7·3V
-6·6V
RV6 at max
R250 4·7k
C247 100
R253 330
R252 2·2k
R248 180
R247 3·3k
C246 100
OUTPUT AMPLIFIER
R227 1k
C219 100
R228 10k
SET METER CAL
RV218 1k
TM7123
from local oscillator TM6965 (Fig. 6.2)
SD FUNCTION
a NORMAL
b AFC
c BFO
d CALIBRATE
SC VOLTMETER RANGE
a 0
b 10
c 20
d 30
e 40
f 50
g 60
dB GAIN
9 & 10 TPE667

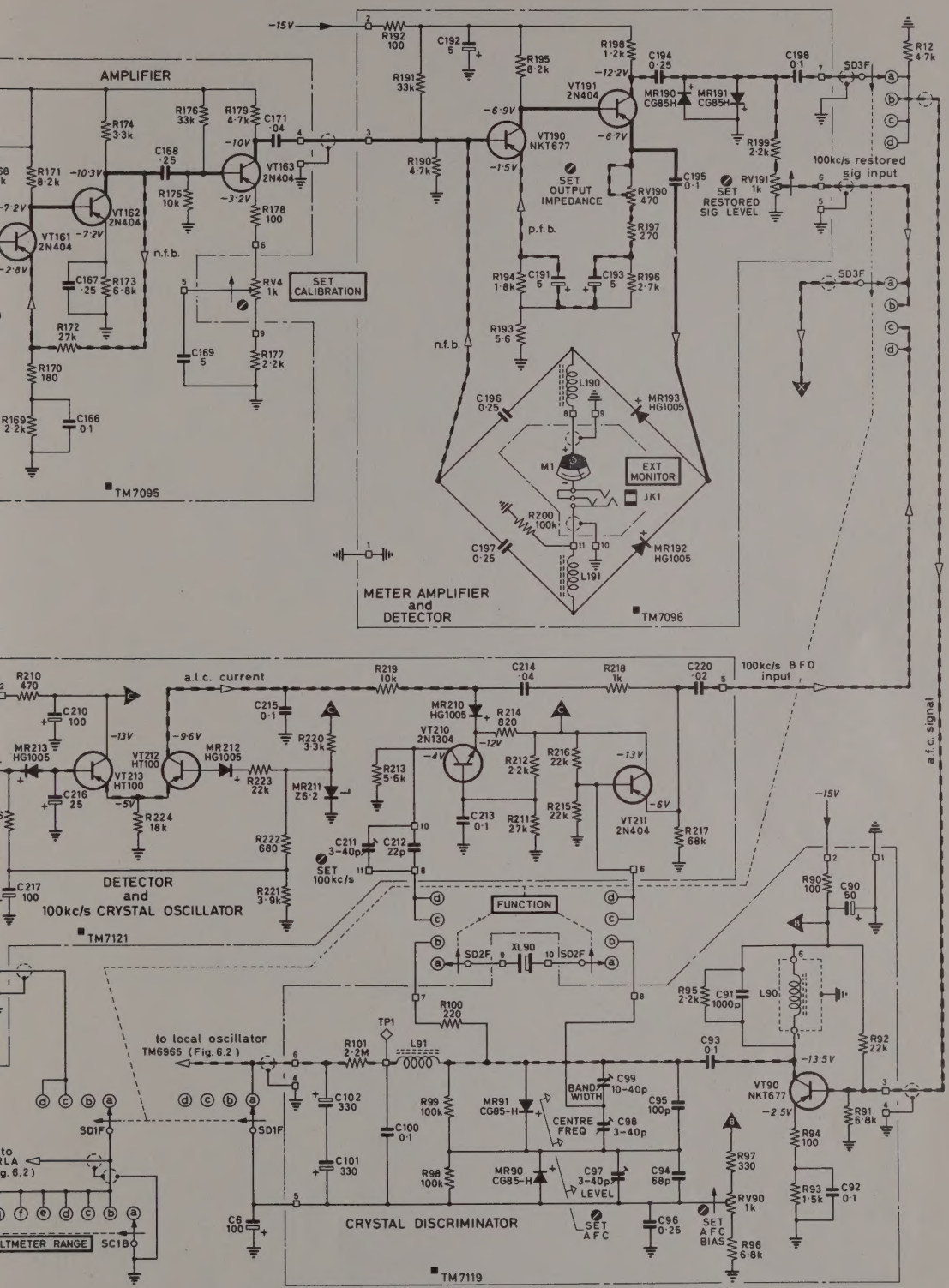


Fig. 6.3 I.F. and output stages

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